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Explorer Peary ready for his dash to the North Pole.

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AN INTRODUCTION TO SCIENCE

BY

BERTHA M. CLARK, Ph.D.

“

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CLARK, INTRODUCTION TO SCIENCE

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TO THE
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FOREWORD

THIRTY years ago the study of science was fighting for a position of academic respectability much as the various special sciences are fighting for the same position to-day. Science edged its way in through the popular fourteen weeks in physics or chemistry, which afforded a very valuable scientific interpretation of the immediate environment of the pupils. But when the colleges agreed to accept science for entrance on the same basis as mathematics and the foreign languages, they prescribed the content of the science courses and totally changed their character. The new syllabi were determined by college professors who had in mind only the needs of the pupils destined to go to college.

For these reasons, without real blame being attributable to any one, the proper aim of the study of science in the high schools was defeated. Disturbers of the educational peace then pointed to the fact that approximately only five per cent of the high school pupils go to college. They questioned the dictum that the best education for the pupil preparing for college is the best education for the pupil going immediately into active life. It was pointed out that everybody who took science was being forced to study a great deal of pure theory that could not be connected with practical life without much subsequent study.

The first movement toward a reformation of this unfortunate condition was the organization of short courses in biology for the first year of the high school. When this science was studied for its human relations, an immediate change in the

interest and success of the pupils was evident. However, this course did not furnish a basis for preparation acceptable to the colleges, and a long and acrimonious debate ensued. As the high school came to be more and more conscious of itself, schools here and there boldly insisted that they would settle their own problems, and many prepared courses which were of vital interest and importance to the pupils. One of the first books to lead the way in reconstructing the subjects of physics and chemistry was *General Science*, by Doctor Bertha M. Clark of the William Penn High School. Doctor Clark began this book after an exhaustive questionnaire had been sent to graduates of the William Penn High School, which proved that the traditional physics had been to the pupils an object of no real value and of almost universal dislike. The reformed general science, on the contrary, immediately proved to be a very popular course in the school. Pupils brought to the class their home problems for scientific analysis. Heating, lighting, and ventilating the home, the analysis of foods, the detection of adulterants, the composition of fabrics, the removal of stains, and a thousand practical, everyday questions showed the improved relation of the rejuvenated science to life.

General Science as a pioneer was a marked success. The present volume is an extension of the general science idea to cover a broader field. When the history of American education of the first two decades of the twentieth century shall be written, this movement to humanize science will prove one of its interesting chapters, and the present volume and its precursor will undoubtedly appear as landmarks along the road of real educational service.

W. D. LEWIS,

Principal of William Penn High School.

PREFACE

SCIENTIFIC knowledge and scientific management are at the root of all successful present-day projects and enterprises. The business man who would keep his place in the modern competitive struggle must have a thorough knowledge of the factors which enter into his business and must know how to utilize these factors in a constructive scientific way. Not only the lives of staid business men, but also the lives of youths and maidens are full of projects. The setting up of a homemade telephone is as important an enterprise to the youth as is the forging ahead in business to the mature man; the planning of a trial menu for household use is as great a project to a high school girl as is the direction of a dietary kitchen to a skilled dietitian.

The aim of this book is to start young high school pupils on scientific projects which will influence for good their *present* lives, and which under different guise will equally influence for good their future lives. Among the scientific projects presented to the pupils are those of the selection of economic menus of dietary standards; the selection of suitable paints, oils, and varnishes for actual daily use; the examination of different fuels, and their adaptability to furnace and kitchen range; the investigation of home and school lighting and its influence on eyesight; the utilization of simple labor-saving devices to relieve physical exertion; the employment of chemical agents to transform useless waste products, such as grease and sewage, into useful products, such as soaps and fertilizers; and the application of hygienic facts and theories to school, home, and community sanitation.

I am indebted to many for the illustrations which are used in the text. Acknowledgment is made to Professor Alvin

Davison for Figs. 23, 27, 37, 38, 44-46, 71, 317; to G. W. Hunter for Figs. 30, 306, 308, 311; to Messrs. Blackwelder and Barrows for Figs. 5, 226, 228, 229, 234-237, 242, 244, 256, 257, 259, 260, 271, 276, 278, 284; to Messrs. Mayne and Hatch for Figs. 302, 307, 321, 325, 333, 334; to J. G. Coulter for Figs. 43, 295; to Dr. C. R. Dryer for Figs. 216, 231, 258, 262, 267, 272, 275; to E. F. Andrews for Figs. 290-292, 299, 300, 303, 304. Acknowledgment is also made to Miss Alma Waldie, Miss Helen Shriver, Mr. A. H. Rosewig, and Mr. Philip Lee.

Illustrations have been freely given by The American Radiator Co., General Electric Co., Hershey Chocolate Co., *Scientific American*, Aluminum Cooking Utensil Co., Goulds Manufacturing Co., Carnegie Institution, Illuminating Engineering Society, U. S. Bureau of Fisheries, U. S. Department of Agriculture, Canadian Pacific R.R., Northern Pacific R.R., Johns Hopkins Press, and many other firms and publishers.

Mr. W. D. Lewis, Principal of the William Penn High School, has given the stimulus of his interest and approval. Miss Helen Hill, Librarian of the school, has kept me supplied with the most recent publications of practical scientific interest and has been of invaluable service in numerous ways. Miss Mathilde Droege of the Brearley School, New York, has read the manuscript and made many helpful suggestions.

Without the coöperation of the science teachers of the William Penn High School, the writing of the book would have been difficult. They have tested and retested projects, have criticized again and again, and have coöperated in every way to make successful the book and the course on which it is based. Among those who have given most freely of their time are Miss Jean Weber and Miss May Laramay. Thanks are also due to Miss Helen Price, Miss Ruth Flanagan, Miss Anna Biddle, and Miss Catherine Way.

BERTHA MAY CLARK.

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AN INTRODUCTION TO SCIENCE

CHAPTER I

HEAT

Value of fire.—Every day, uncontrolled fire wipes out human lives and destroys vast amounts of property; every day, fire, controlled and regulated in stove and furnace, cooks our food and warms our houses. Fire melts ore and allows the forging of iron, as in the blacksmith's shop, and the fashioning of innumerable objects serviceable to man. Heated boilers change water into the steam which drives our engines on land and sea. Heat causes rain and wind, fog and cloud; heat enables vegetation to grow and thus indirectly provides our food. Whether heat comes directly from the sun or from artificial sources such as coal, wood, oil, or electricity, it is vitally connected with our daily life, and the facts and theories relative to it are among the most important that can be studied.

General effect of heat. *Expansion and contraction.*—One of the best-known effects of heat is the change which it causes in the size of a body. Every housewife knows that when a kettle is filled with cold water and heated, there is an overflow as soon as the water becomes hot. Heat causes not only water, but all other liquids, to occupy more space, or to expand, and in some cases the expansion, or increase in size, is surprisingly large. If 100 pints of ice water, for example, are heated in a kettle, the 100 pints steadily expand until, at the boiling point, they occupy as much space as 104 pints of ice water.

The expansion of water can be easily shown by heating a

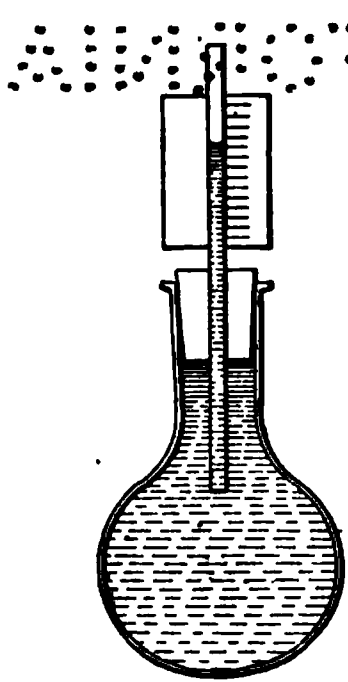


FIG. 1. — As the water becomes warmer, it expands and rises in the narrow tube.

flask (Fig. 1) filled with water and closed by a cork through which a narrow tube passes. As the water is heated, it expands and forces its way up the narrow tube. If the heat is removed, the liquid cools, contracts, and slowly falls in the tube, resuming in time its original size or volume. A similar observation can be made with alcohol, mercury, or any other convenient liquid.

Not only liquids are affected by heat and cold, but solids also are subject to similar changes. A metal ball which when cool just slips through a ring is, when heated, too large to slip through the ring. Telegraph and telephone wires in winter are stretched taut from pole to pole. In summer, when they are exposed to the fierce rays of the sun, they expand and sag until they are much too long. If the wires were stretched taut in the summer, there would not be sufficient leeway for the contraction which accompanies cold weather, and they would snap under the strain.

Air expands greatly when heated (Fig. 2), but since air is practically invisible, we are not ordinarily conscious of any change in it. The expansion of air can be readily shown by putting a drop of ink in a thin glass tube, inserting the tube in the cork of a flask, and applying heat to the flask (Fig. 3). The ink is forced up the tube by the expanding air. Even the warmth of the hand is generally sufficient to cause the drop to rise steadily in the tube. The rise of the drop of ink shows that the air in the flask

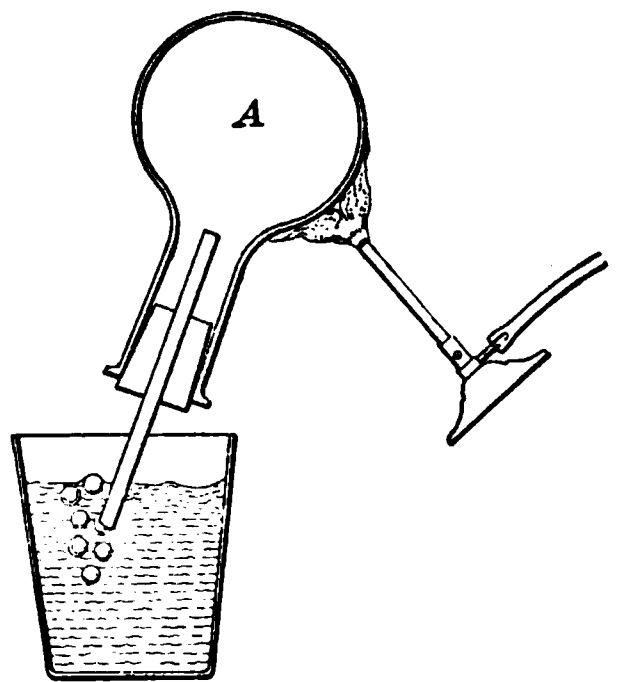


FIG. 2. — As the air in A is heated, it expands and escapes in the form of bubbles.

occupies more space than formerly, and since the quantity of air has not changed, each cubic inch of space must hold a less weight of warm air than it held of cold air; that is, one cubic inch of warm air weighs less than one cubic inch of cold air, or, warm air is less dense than cold air. All gases which are not confined expand when heated and contract as they cool. Heat, as a general rule, causes substances to expand or become less dense.

Amount of expansion and contraction. — While most substances expand when heated and contract when cooled, they are not all affected equally by the same changes in temperature. Alcohol expands more than water, and water more than mercury. Steel wire which measures $\frac{1}{4}$ mile on a snowy day gains 25 inches in length on a warm summer day, and an aluminum wire under the same conditions gains 50 inches in length.

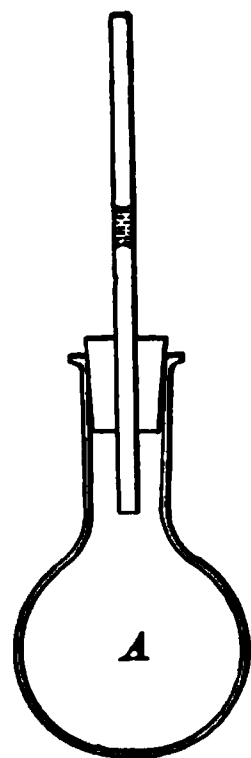


FIG. 3. — As the air in A is heated, it expands and forces the drop of ink up the tube.

Advantages and disadvantages of expansion and contraction. — We owe the snug fit of metal tires and bands to the expansion and contraction resulting from heating and cooling. The tire of a wagon wheel is made slightly smaller than the wheel which it is to protect; it is then put into a very hot fire and heated until it has expanded sufficiently to slip on the wheel. As the tire cools it contracts and fits the wheel closely.

In building a railroad, spaces are usually left between consecutive rails in order to allow for expansion during the summer.

The unsightly cracks and humps in cement floors are sometimes due to the expansion resulting from heat (Fig. 4). Cracking from this cause can frequently be avoided by cutting the soft cement into squares, the spaces between them giving opportunity for expansion just as do the spaces between the rails of railroads.

In the construction of long wire fences provision must be made for tightening the wire in summer, otherwise they sag.

Heat plays an important part in the splitting of rocks and in the formation of *débris*. Rocks in exposed places are greatly



FIG. 4. — A cement walk broken by expansion due to sun heat.

affected by changes in temperature, and in regions where the changes in temperature are sudden, severe, and frequent, the rocks are not able to withstand the strain of

expansion and contraction, and as a result crack and split. In the Sahara Desert much crumbling of the rock into sand has been caused by the change from the intense heat of the day to the intense cold of night. The heat of day causes the rocks to expand, and the cold of night causes them to contract, and these two forces constantly at work loosen the grains of the rock and force them out of place, thus causing the rocks to crumble.

The surface of the rock is the most exposed part, and during the day the surface, heated by the sun's rays, expands, becomes too large for the interior, and crumbles and splits as a result of the strain. With the sudden fall of temperature in the late afternoon and night, the surface of the rock becomes greatly chilled and colder than the rock beneath; the surface rock therefore contracts and shrinks more than the underlying rock, and again splits and crumbles (Fig. 5).

FIG. 5 — Summit of Mt. Whitney.

On bare mountains, the heating and cooling effects of the

sun are very striking. The surface of many a mountain peak is covered with cracked rock so insecure that a touch or step will dislodge the fragments and start them down the mountain slope. The lower levels of mountains (Fig. 6) are frequently buried several feet under *débris* which has been formed in this way from higher peaks, and which has slowly accumulated at the lower levels. Under the action of heat and cold exposed rock "weathers"; that is, it cracks and crumbles into fragments which can be blown away by wind and washed away by water. Heat and cold are powerful agents of weathering.

General effect of heat.

Change in temperature.

— Perhaps the best-known effect of heat is

FIG. 6. — *Débris* formed from crumbling rock.

the warmth it imparts to substances which come under its influence. In summer the sun's rays heat the cement walks until they burn the feet; in winter, the coals glowing in furnace and stove heat the icy air, and make it warm. When an object feels hot to the touch, we say it has a high temperature; when it feels cold to the touch, that it has a low temperature. Changes in temperature are caused by heat: when cold water, that is, water with a low temperature, is placed over glowing coal it becomes warm water, that is, water with a high temperature. The change in the temperature of the water is due to the heat given out from the burning fuel. As the fire dies out, it

imparts less and less warmth to the water, which slowly cools to a lower temperature.

Man is a poor judge of temperature. — Man is not an accurate judge of temperature. Ice water seems comparatively warm after eating ice cream, and yet we know that ice water is by no means warm. A room may seem warm to a person who has been walking in the cold air, while it may feel decidedly cold to one who has come from a warmer room. If the hand is cold, lukewarm water feels hot, but if the hand has been in very hot water and is then transferred to lukewarm water, the

latter seems cold. We see that the sensation or feeling of warmth is not an accurate guide to the temperature of a substance; and yet until 1592, one hundred years after the discovery of America, people relied solely upon their sensations for the measurement of temperature! The necessity, as well as the convenience, of having some accurate means of determining the temperature of substances led to the invention of the thermometer, an instrument whose operation depends upon the fact that most substances expand when heated and contract when cooled.



FIG. 7. —
Making a
thermometer.

The thermometer. — The modern thermometer consists of a glass tube at the lower end of which is a bulb filled with mercury or colored alcohol (Fig. 7). After the bulb has been filled with the mercury, it is heated a little above the boiling point of water and the tube is then sealed at the top. As the mercury cools, it falls and leaves an unoccupied space or vacuum above it. The thermometer is then placed in a beaker of water and the water is heated by a Bunsen burner. As the water becomes warmer and warmer the level of the mercury in the tube steadily rises until the water boils, when the level remains stationary (Fig. 8). A

scratch is made on the tube to indicate the point to which the mercury rises when the bulb is placed in boiling water, and this point is marked 212° . The tube is then removed from the boiling water, and after cooling for a few minutes, it is placed in a vessel containing finely chopped ice (Fig. 9). The mercury column falls rapidly, but finally remains stationary, and at this level another scratch is made on the tube and the point is marked 32° . The space between these two points, which represent the temperatures of boiling water and of melting ice, is divided into 180 equal parts called degrees. The thermometer in use in the United States is marked in this way and is called the Fahrenheit thermometer after its designer.

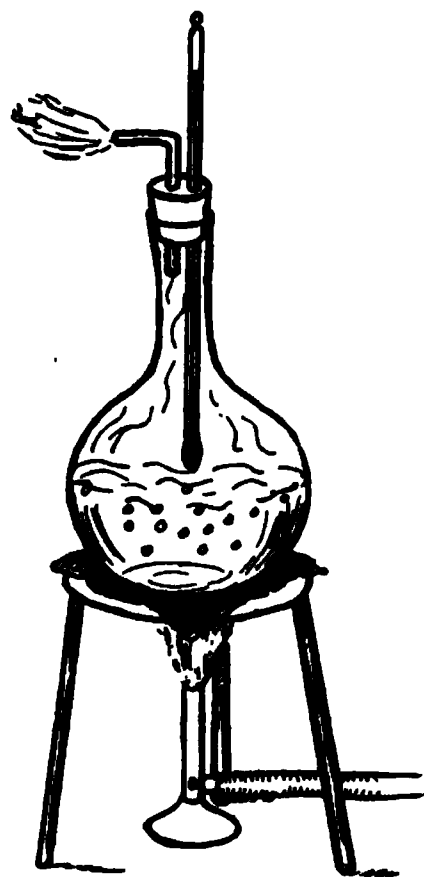


FIG. 8. — Determining one of the fixed points of a thermometer.

The Centigrade thermometer, in use in foreign countries and in all scientific work, is similar to the Fahrenheit except that the fixed points are marked 100° and 0° ; and the interval between the points is divided into 100 equal parts instead of into 180.

The boiling point of water is 212° F. or 100° C.

The melting point of ice is 32° F. or 0° C.

Glass thermometers of the above type are the ones most generally used, but there are many different types for special purposes (Fig. 10).

Some uses of a thermometer. — One of the chief values of a thermometer is the service it has rendered to medicine. When a thermometer is held for a few minutes under the tongue of a normal, healthy person, the mercury rises to about 98.4° F. When the temperature of the body

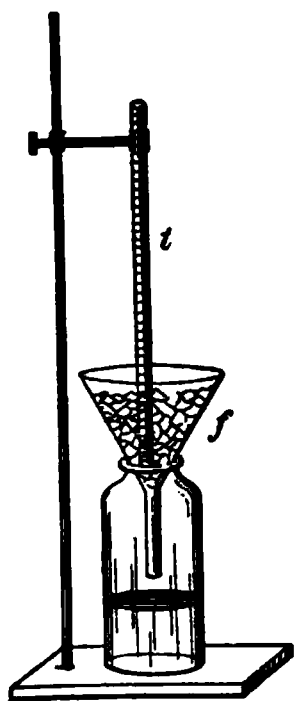


FIG. 9. — Determining the lower fixed point of a thermometer.

varies even though only slightly from this point, a physician should be consulted immediately. The temperature of the body is a trustworthy indicator of general physical condition; hence in all hospitals the temperature of patients is carefully taken at stated intervals.

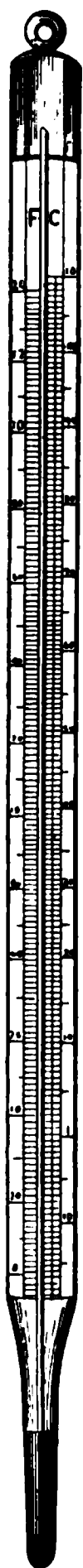


FIG. 10.—A well-made commercial thermometer.

Commercially, temperature readings are extremely important. In sugar refineries the temperature of the heated liquids is observed most carefully, since a difference in temperature, however slight, affects not only the general appearance of sugars and sirups, but the quality as well.

The many varieties of steel show the influence which heat may have on the nature of a substance. By experiment it has been found that if hardened steel is heated to about 450° F. and quickly cooled, a steel is produced which is suitable for razors; if heated to about 500° F. and then cooled, the metal is much coarser and is suitable for shears and farm implements; while if it is heated but 50° F. higher, that is, to 550° F., it gives the fine elastic steel of watch springs.

A thermometer can be put to good use in every kitchen; the inexperienced housekeeper who cannot judge of the "heat" of the oven will be saved bad bread, if the thermometer is a part of her equipment. The thermometer can also be used in detecting adulterants. Butter should melt at 94° F.; if it does not, you may be sure that it is adulterated with suet or other cheap fat. Olive oil should be a clear liquid above 75° F.; if, above this temperature, it looks cloudy, you may be sure that it, too, is adulterated with fat.

Methods of heating buildings. *Open fireplaces and stoves.* — If heat did not cause expansion and change in temperature, it would be impossible to heat our houses and to protect ourselves against the biting blasts of winter. The burning coal warms and expands the air within the furnace, causing it to rise through the stovepipes and thus to carry heat to the different parts of the house. Open fireplaces, old-fashioned stoves, and new-fashioned furnaces owe their existence to these two effects of heat. In olden times, man heated his modest dwelling by open fires alone. The burning logs gave warmth to the cabin and served as a primitive cooking agent; and the smoke which usually accompanies burning was carried away through the chimney. But in an open fireplace much heat escapes with the smoke and only a small portion streams into the room and gives warmth.

When fuel is placed in an open fireplace (Fig. 11) and lighted, the air immediately surrounding the fire becomes warmer and, because of expansion, becomes lighter than the cold air above. The cold air, being heavier, falls and forces the warmer air upward, and with the warm air goes the disagreeable smoke. The fall of the colder and heavier

FIG. 11. — The open fireplace as an early method of heating.

air, and the rise of the warmer and hence lighter air, is similar to the exchange which takes place when water is poured upon oil; water, being heavier than oil, sinks to the bottom and forces the oil to the surface.

As the air is heated by the fire, it expands and is pushed up the chimney by the cold air which is constantly entering through loose windows and doors. Open fireplaces are very healthful because the air which is driven out is impure, while the air which rushes in is fresh, and brings oxygen.

But open fireplaces, while pleasant to look at, are not efficient for heating, because most of the heat escapes through the chimney and only a small portion remains in the room where warmth is needed. Neither are open fireplaces practical for cooking, because there is no convenient arrangement for placing cooking utensils over the burning fuel. Owing to the loss of heat from open fireplaces, and their inconvenience in cooking, the invention of stoves was a great advance in efficiency, economy, and comfort. A stove is a receptacle for fire, provided with a definite inlet or draft for air and a definite outlet to the chimney for smoke, and able to radiate into the room most of the heat produced from the fire which burns within. The inlet, or draft, admits enough air to cause the fire to burn brightly or slowly, as the case may be. When we wish a hot fire, the draft should be opened wide and enough air secured to produce a strong glow. When we wish a low fire, the inlet should be partly closed, and just enough air admitted to keep the fuel smoldering.

When the fire is started, the outlet damper should be opened wide in order to allow the escape of smoke; but after the fire is well started there is less smoke, and the damper may be partly closed. If the damper is kept open, coal is rapidly consumed, and the additional heat passes out through the chimney and is lost.

Furnaces. *Hot air.* — The labor involved in the care of numerous stoves is considerable, and the use of a central heating stove, or furnace, is a great saving in strength and fuel. A furnace is a stove arranged as in Figure 12. The

stove *S*, like all other stoves, has an inlet for air and an outlet *C* for smoke; but in addition, it has built around it a chamber in which air circulates and is warmed. The air warmed by the stove is forced upward by cold air which enters from outside. For example, cold air constantly entering at *F* drives the air heated by *S* through pipes and ducts to the rooms to be heated.

The metal pipes which convey the heated air from the furnace to the ducts are sometimes covered with felt, asbestos, or other non-conducting material in order that heat may not be lost during transmission. The ducts which receive the heated air from the pipes are built

FIG. 12. — A furnace. Pipes conduct hot air to the rooms.

in the non-conducting walls of the house, and hence lose practically no heat. The air which reaches halls and rooms is therefore warm, in spite of its long journey from the cellar.

Not only houses are warmed by a central heating stove, but whole communities sometimes depend upon a central heating plant. In the latter case, pipes closely wrapped with a non-conducting material carry steam long distances underground to remote buildings. Overbrook and Radnor, Pa., are towns in which such a system is used.

Hot-water heating. — The heated air which rises from furnaces is seldom hot enough to warm large buildings well; hence furnace heating is being largely supplanted by hot-water heating.

The principle of hot-water heating is shown by the following simple experiment. Two flasks and two tubes are arranged as in Figure 13, the upper flask containing a colored liquid and the lower flask, clear water. If heat is applied to *B*, one can see at the

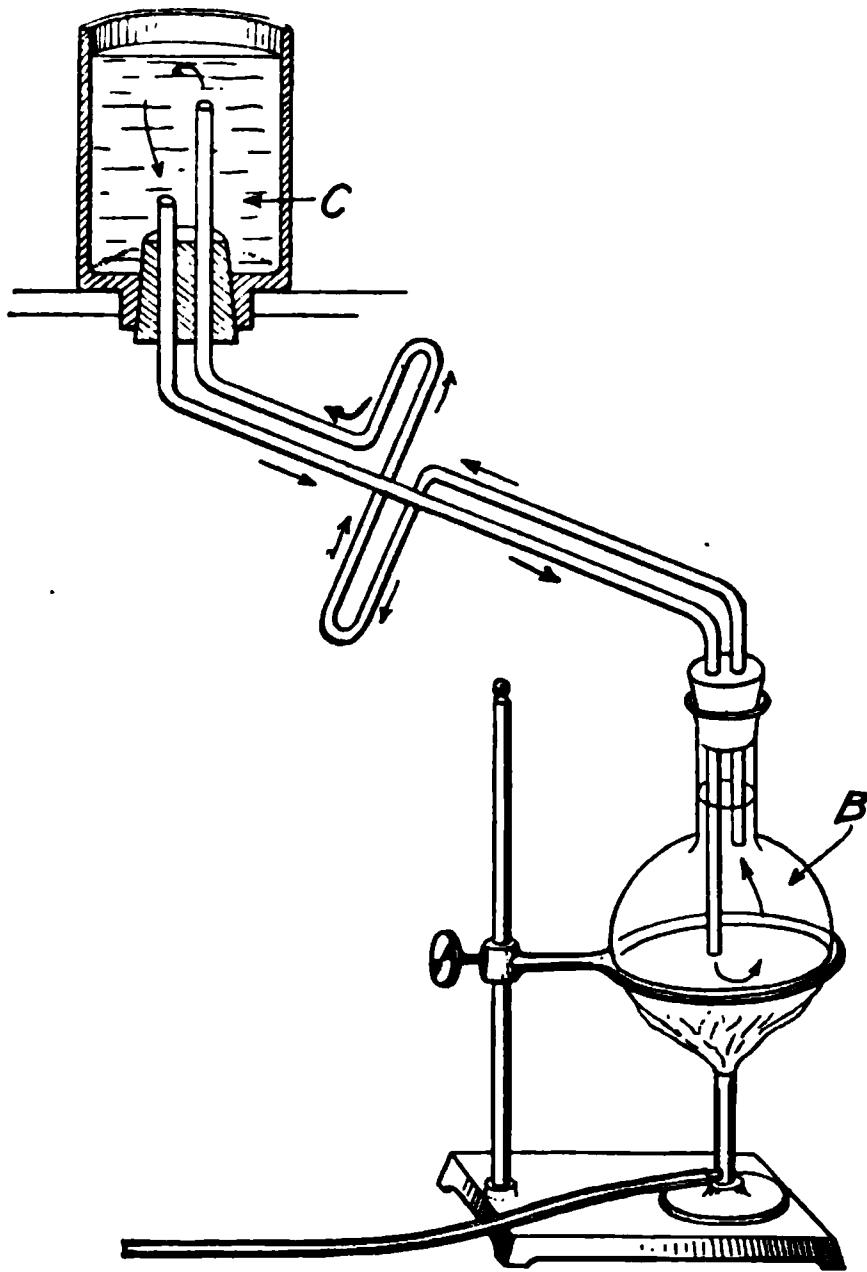


FIG. 13. — The principle of hot-water heating.

end of a few seconds the downward movement of the colored liquid and the upward movement of the clear water. If we represent a boiler by *B*, a radiator by the coiled tube, and a safety tank by *C*, we shall have a very fair illustration of the principle of a hot-water heating system. The hot water in the radiators cools and, in cooling, gives up its heat to the rooms and warms them. In hot-water heating systems, fresh air is not brought to the rooms, for the radiators are closed pipes containing hot

water (Fig. 14). For this reason it is necessary to raise windows at intervals.

Some systems of hot-water heating secure ventilation by confining the radiators to the basement, to which cold air from outside is constantly admitted in such a way that it circulates over the radiators and becomes strongly heated. This warm fresh air then passes through ordinary flues to the rooms above. In Figure 15, a radiator is shown in a boxlike structure in

FIG. 14. — Hot-water heating.

FIG. 15 — Fresh air from outside circulates over the radiators and then rises into the rooms to be heated.

the cellar. Fresh air from outside enters a flue at the right, passes over the radiators, where it is warmed, and then makes its way to the room through a flue at the left. The warm air

FIG. 16. — The air which goes to the schoolrooms is warmed by passage over the radiators.

which enters the room is thoroughly fresh. Figure 16 shows how a schoolroom is supplied with warm fresh air. The actual labor involved in furnace heating and in hot-water heating is practically the same, since coal must be fed to the fire, and ashes must be removed; but the hot-water system has the advantage of economy and cleanliness.

Fresh air. — Currents of fresh air are essential to normal, healthy living; and 2000 cubic feet of fresh moving air per hour is desirable for each individual. If a gentle breeze is blowing, the barely perceptible lowering of a window will give the needed air currents, even if there are no additional drafts of fresh air through other openings. Most houses are so loosely constructed that small currents of fresh air constantly enter through cracks and crevices in loose doors, floors, and windows. But except in case of high winds, this supply is never sufficient in itself. It should be increased by currents of air admitted through slightly lowered windows, or brought in by means of a special ventilating system.

In the preceding section, we learned that many houses heated by hot water are supplied with fresh-air pipes which admit fresh air into the rooms. In some cases the amount which enters is so great that the air in a room is changed three or four times an hour. The constant inflow of cold air and exit of warm air necessitates larger radiators and more hot water and more coal to heat the larger quantity of water, but the additional expense is more than compensated by the gain in health.

Wind and currents. — The gentlest summer breezes and the fiercest blasts of winter are produced by the unequal heating of air. We have seen that the air nearest to a stove or hot object becomes hotter than the adjacent air, that it tends to expand and is replaced and pushed upward and outward by colder, heavier air falling downward. We have learned

also that the moving liquid or gas carries heat which it gradually gives out to surrounding bodies. When a liquid or a gas moves away from a hot object, carrying heat with it, the process is called convection.

Convection is responsible for winds and ocean currents, for land and sea breezes, and other daily phenomena. The Gulf Stream illustrates the transference of heat by convection. A large body of water is strongly heated at the equator, and then moves away, carrying heat with it to distant regions, such as England and Norway.

Owing to the shape of the earth and its position with respect to the sun, different portions of the earth are unequally heated. In those portions where the earth is greatly heated the air likewise is heated, and there is a tendency for the air to rise, because the cold air from surrounding regions rushes in and forces the less dense air upward. In this way winds are produced. There are many circumstances which modify winds and currents, and it is not always easy to explain their direction and velocity, but one very definite cause of winds and currents is the unequal heating of the surface of the earth.

Conduction. — A poker used in stirring a fire becomes hot, and heats the hand grasping the poker, although only the opposite end of the poker has actually been in the fire. Heat from the fire passes into the poker, travels along it, and warms it. When heat flows in this way from a warm part of a body to a colder part, the process is called conduction. A flatiron is heated by conduction, the heat from the warm stove passing into the cold flatiron and gradually heating it.

In convection, air and water circulate freely, carrying heat with them; in conduction, heat flows from a warm region toward a cold region, but there is no apparent motion of any kind.

Heat travels more readily through some substances than through others. All metals conduct heat well; irons placed on the fire become heated throughout and cannot be grasped with the bare hand; iron utensils are frequently made with wooden handles, because wood is a poor conductor and does not allow heat from the iron to pass through it to the hand. For the same reason a burning match may be held without discomfort until the flame almost reaches the hand.

Stoves and radiators are made of metal, because metals conduct heat readily, and as fast as heat is generated within the stove by the burning of fuel, or introduced into the radiator by the hot water, the heat is conducted through the metal and escapes into the room.

Hot-water pipes and steam pipes are usually wrapped with a non-conducting substance, or insulator, such as asbestos, in order that the heat may not escape, but may be retained within the pipes until it reaches the radiators in the rooms.

The old-fashioned out-of-door brick ovens (Fig. 17), used so much by our grandparents, depended for their value on the fact that bricks are poor conductors of heat. These huge ovens were built out in the open, and just before the family baking was to be done, large logs were

FIG. 17. — An old-fashioned out-of-door brick oven

thrust into the oven and set afire. The logs in burning heated the oven, and when they had heated it sufficiently, they were quickly removed. The bread to be baked was then placed in the hot oven, the opening was closed, and the oven left to take care of itself. Bricks are poor conductors of heat, and the heat left by the burning logs did not escape, but remained to bake the bread.

The fireless cooker and the refrigerator. — The invention of the "fireless cooker" depended in part upon the principle of non-conduction. Two vessels, one inside the other, are



FIG. 18. — A fireless cooker.

separated by sawdust, asbestos, or other poor conducting material (Fig. 18). Foods are heated in the usual way to the boiling point or to a high temperature, and are then placed in the inner vessel. The heat of the food cannot escape through the non-

conducting material which surrounds it, and hence remains in the food and slowly cooks it.

A very interesting experiment for testing the power of non-conductors to retain heat can be easily performed at home. Put some hot water, at about 75° F., in a vessel covered with wool or felt, and an equal quantity at the same temperature in an uncovered vessel of the same kind. By means of thermometers notice the rapidity with which the water cools in the uncovered vessel, and the slowness with which it cools in the covered vessel. Evidently the non-conductor serves to retain the heat within the vessel and to prevent its escape into the air.

The refrigerator (Fig. 19), a much older invention than the fireless cooker, is likewise based upon the principle that certain substances are poor conductors. In the fireless cooker, we wish to prevent the escape of heat from the vessel; but in the refrigerator we wish to prevent its entrance. The power of a non-conductor to keep out heat is tested in a simple way. Put some ice-cold water in a covered vessel, and an equal quantity in an uncovered vessel. By means of a thermometer notice the rapidity with which the water warms in the uncovered vessel, and the slowness with which the water warms in the covered vessel. The heat in the air cannot pass readily through the felt, and hence the water in the covered bottle is warmed much more slowly than the water in the uncovered bottle.

FIG. 19. — A refrigerator.

Wood is a poor conductor of heat, and hence refrigerators are usually made of thick wood; in addition, the space between the walls is often filled with a non-conductor, such as mineral wool or sawdust. A refrigerator in order satisfactorily to chill the food within it must have its ice section placed at the top. The air surrounding the ice is chilled and falls; the less cool air is pushed up and takes its place, but becoming rapidly chilled, it in turn falls (Fig. 20). In this way a constant circulation of cold air is maintained within the refrigerator

FIG. 20. — Circulation of air in a refrigerator.

and the food is preserved. Hot or even warm food should not be put into a refrigerator and the door should not be left open, admitting warm air from outside.

Picnickers carry hot drinks and cold drinks in straw-covered bottles; the straw keeps the hot drink hot because it prevents the escape of heat; it keeps the cool drink cool because it prevents the entrance of heat from the outside. The "vacuum" bottles so much used to prevent change in the temperature of liquids utilizes a double-walled bottle with a vacuum between the walls. In this vacuum there is practically no matter to conduct heat, therefore the temperature changes very little in a long time.

Effect of heat. — A third effect of heat has a vital influence on our lives because to it we owe the changes which take place when food is cooked. The doughy mass which goes into the oven comes out a light spongy loaf; the hard, tough beet comes out the soft succulent vegetable; the small, hard, indigestible rice grain comes out the swollen, fluffy, and digestible grain. If heat did not bring about a change in the nature of substances, many of our present foods would be useless because they cannot be digested in a raw state.

Coal may be heated in such a way that it will break up into illuminating gas and into substances that yield beautiful dyes. Wood may be treated in such a way that it will form charcoal. Whenever heat causes such changes in the nature of a substance, it is said to produce a chemical change in that substance. Of course chemical changes can take place without heat, but some of the most striking of these changes, such as the breaking up of coal into illuminating gas and coke, take place only with the application of heat.

CHAPTER II

TEMPERATURE AND HEAT

Temperature is not a measure of the amount of heat in a body. — If two similar basins containing unequal quantities of water are placed in the sunshine on a summer day, the smaller quantity of water will become quite warm in a short period of time, while the larger quantity will become only lukewarm. Both vessels receive the same amount of heat from the sun, but in one case the heat is utilized in heating a small quantity of water to a high temperature, while in the second case the heat is utilized in warming a larger quantity of water to a lower degree. Equal amounts of heat do not necessarily produce equivalent temperatures, and equal temperatures do not necessarily indicate equal amounts of heat. It takes more heat to raise a gallon of water to the boiling point than it does to raise a pint of water to the boiling point, but a thermometer registers the same temperature in the two cases. The temperature of boiling water is 100° C. whether there is a pint of it or a gallon. Temperature is independent of the quantity of matter present; but the amount of heat contained in a substance at a certain temperature is not independent of quantity, being greater in the larger quantity.

The unit of heat. — It is necessary to have a unit of heat, just as we have a unit of length, or a unit of mass, or a unit of time. One unit of heat is called a *calorie*, and is the amount of heat which will change the temperature of 1 gram of water 1° C. It is the amount of heat given out by 1 gram of water when its temperature falls 1° C., or the amount of heat ab-

sorbed by 1 gram of water when its temperature rises 1° C. If 400 grams of water are heated from 0° to 5° C., the amount of heat which enters the water is equivalent to 5×400 or 2000 calories; if 200 grams of water cool from 25° to 20° C., the heat given out by the water is equivalent to 5×200 , or 1000 calories.

Some substances heat more readily than others.—When two equal quantities of water at the same temperature are exposed to the sun for the same length of time, their final temperatures are the same. But when equal quantities of different substances are exposed, the temperatures resulting from the heating are not necessarily the same. If a basin containing 1 lb. of mercury is put on the fire, side by side with a basin containing 1 lb. of water, the temperatures of the two substances will be very different at the end of a short time. The mercury will have a far higher temperature than the water, in spite of the fact that the amount of mercury is as great as the amount of water and that the heat received from the fire is the same in each case. Mercury is not as difficult to heat as water, less heat being required to raise its temperature 1° than is required to raise the temperature of an equal quantity of water 1° . In fact, mercury is 30 times as easy to heat as water, and it requires only one thirtieth as much fire to heat a given quantity of mercury 1° as to heat the same quantity of water 1° .

It requires more heat to raise the temperature of water one or more degrees than it does to raise the temperature of an equal weight of any other substance (except hydrogen) the same number of degrees. Practically this same thing can be stated in another way: Water in cooling gives out more heat than any other substance that cools through the same number of degrees. For this reason water is used in foot warmers and in hot-water bags. If a copper lid were used

as a foot warmer, it would give the feet only .095 as much heat as an equal weight of water; if a lead weight were used, it would give only .031 as much heat as water. Flatirons are made of iron because of the "high specific heat" of iron. They heat slowly and cool slowly, and, when once thoroughly heated they supply the laundress with heat sufficient for a long time.

Water and weather. — About four times as much heat is required to heat a given quantity of water one degree as to heat an equal quantity of earth. In summer, when the rocks and the sand along the shore are burning hot, the ocean and

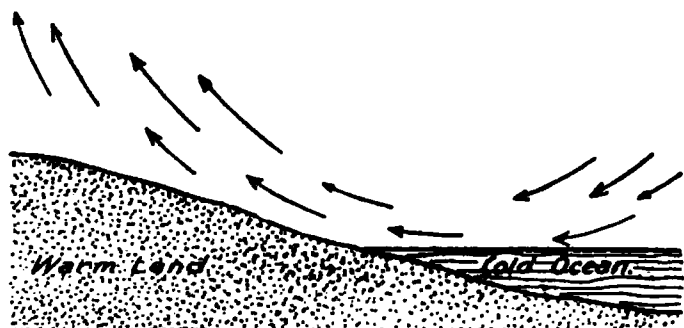


FIG. 21. — An ocean breeze.

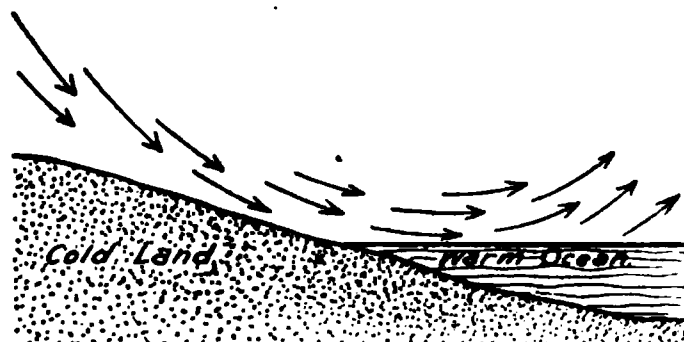


FIG. 22. — A land breeze.

lakes are pleasantly cool, although the amount of heat present in the water is as great as that present in the earth. In winter, long after the rocks and sand have given out their heat and have become cold, the water continues to give out the vast store of heat accumulated during the summer. This explains why lands situated near large bodies of water have less variation in temperature than inland regions. In the summer the water cools the region; in the winter, on the contrary, the water heats the region, and extremes of temperature are not great.

These facts also explain why we sometimes have a land breeze and at other times an ocean breeze. When the air over the land is warmer than that over the ocean, it expands, becomes lighter, and is pushed upward by cooler air which rushes in from over the water. Such an inrush of cooler air from the

ocean is called an ocean breeze. When the air over the ocean is warmer than that over the land the same kind of air movement is caused, but in the opposite direction. Since the air now moves over the surface of the land toward the ocean, it is called a land breeze (Figs. 21 and 22).

Sources of heat. — All of the heat which we enjoy and use we owe to the sun. The wood which blazes on the hearth, the coal which glows in the furnace, and the oil which burns in the stove owe their existence to the sun.

Without the warmth of the sun, seeds could not sprout and develop into the mighty trees which yield firewood. Even coal, which lies buried thousands of feet below the earth's surface, owes its existence to the sun. Coal is simply buried vegetation! Ages ago trees and bushes grew "thick and fast," and the ground was always covered with a deep layer of decaying vegetable matter. In time some of this vast supply sank into the moist soil and became deeply covered with mud. Constant pressure, moisture, and heat affected the underground vegetable mass, and slowly changed it into coal.

The buried forest and thickets were not all changed into coal. Some were changed into oil and gas. Decaying animal matter was often mixed with the vegetable mass. When the mingled animal and vegetable matter sank into moist earth and came under the influence of pressure, it was slowly changed into oil and gas.

The heat of our bodies comes from the foods which we eat. Fruits, grain, etc., could not grow without the warmth and the light of the sun. The animals which supply our meats likewise depend upon the sun for light and warmth.

Therefore, whether heat comes directly from the sun and warms the atmosphere or whether it comes from burning coal, wood, and oil, the sun is its great source.

CHAPTER III

COMMON PHENOMENA DUE TO HEAT

Boiling. — If a kettle of water is placed above a flame, the temperature of the water gradually increases, and soon small bubbles form at the bottom of the kettle and rise through the water. At first the bubbles do not get far in their ascent, but disappear before they reach the surface. Later, as the water gets hotter and hotter, the bubbles become larger and more numerous, rise higher and higher, and finally reach the surface and pass from the water into the air; steam comes from the vessel, and the water is said to *boil*. The temperature at which a liquid boils is called the *boiling point*.

While the water is heating, the temperature steadily rises, but as soon as the water begins to boil the thermometer reading becomes stationary at about 212° F. and does not change, no matter how hard the water boils and in spite of the fact that heat from the flame is constantly passing into the water.

If the gas is turned low, the water boils less hard. If a thermometer is now placed in the water, the temperature registers 212° F. just as it did when the water was boiling hard. This fact enables the thrifty person to economize gas in cooking. As soon as soup, vegetables, or other substances come to a boil, the gas can be partly turned off, and only sufficient used to keep the food gently boiling. It is the heat which cooks the food, and since gently boiling water is just as hot as briskly boiling water, why should extra gas be used for that which yields no return? And yet, how many housewives think to lower the gas as soon as the pot begins to boil? The ap-

plication of the fact that hard boiling water is not any hotter than gently boiling water enables us to save considerable gas and money. Suppose, for example, that three burners of a gas range are being used to boil three separate pots. As soon as the three vessels are all boiling, turn out two gas jets completely, and remove the third vessel from the flaming burner. Then place over the lighted burner a metal plate large enough to hold all three pots. There will be enough heat from the one burner to cause gentle boiling in all three vessels, and the food will cook as quickly as though all three burners were using gas.

Heat necessary to change boiling water to steam. — If the flame which supplies heat is removed from boiling water, the boiling ceases; if the flame is replaced, boiling begins again and some water passes off as steam. Unless heat is constantly supplied, water at the boiling point cannot be transformed into steam.

By experiment it has been found that 536 calories of heat are needed to change 1 gram of water at the boiling point into steam.

Statements similar to the above hold not only for water but also for other liquids. If milk is placed upon a stove, the temperature rises steadily until the boiling point is reached; further heating does not produce a change in temperature, but a change of the water of the milk into steam. As soon as milk, or any other liquid food, comes to a boil, the gas flame should be lowered until only an occasional bubble forms, because so long as any bubbles form the temperature is that of the boiling point, and further heat merely results in waste. Every liquid has its own specific boiling point; for example, alcohol boils at 78.4°C . and water at 100°C .

Condensation. — If a cold lid is held in the steam of boiling water, drops of water gather on the lid; the steam is cooled

by contact with the cold lid and *condenses* into water. Bottles of water brought from a cold cellar into a warm room become covered with fine drops of water, because the moisture in the air, chilled by contact with the cold bottles, condenses into drops of water. Glasses filled with ice water show a similar mist.

We have seen that 536 calories are required to change 1 gram of water into steam; if, now, the steam in turn condenses into water, it is natural to expect a release of the heat used in transforming water into steam. Experiment shows not only that vapor gives out heat during condensation, but that the amount of heat thus set free is exactly equal to the amount absorbed during vaporization!

Practical application. — We understand now the value of steam as a heating agent. Water is heated in a boiler in the cellar, and the steam passes through pipes which run to the various rooms; there the steam condenses into water in the radiators, each gram of steam setting free 536 calories of heat. When we consider the size of the radiators and the large amount of steam which they contain, and consider further that each gram in condensing sets free 536 calories, we understand the ease with which buildings are heated by steam.

Most of us have at times profited by the heat of condensation. In cold weather, when there is a roaring fire in the range, the water frequently becomes so hot that it “steams” out of open faucets. If, at such times, the hot water is turned on in a small cold bathroom, vapor condenses on windows, mirrors, and walls, and the cold room becomes perceptibly warmer. The heat given out by the condensing steam passes into the surrounding air and warms the room.

There is, however, another reason for the rise in temperature. If a large pail of hot soup is placed in a larger pail of cold water, the soup will gradually cool and the cold water

will gradually become warmer. A red-hot iron placed on a stand gradually cools, but warms the stand. A hot body loses heat as long as a cooler body is near it; the cold object is heated at the expense of the warmer object, and one loses heat and the other gains heat until the temperature of both is the same. Now the hot water in the tub gradually loses heat and the cold air of the room gradually gains heat by convection, but the amount given the room by convection is small compared with the large amount set free by the condensing steam.

Distillation. — When impure, muddy water is boiled, drops of water collect on a cold plate held in the path of the steam, but the drops are clear and pure. When impure water is

boiled, the steam from it does not contain any of the impurities because these are left behind in the vessel. If all the water is allowed to boil away, a layer of mud or of other impurities will be found at the bottom of the vessel. Because of this fact, it is possible to purify water in a very simple way. Place over a fire a large kettle closed except for a spout which is long enough to reach

FIG. 23. — In order that the steam which passes through the coiled tube may be quickly cooled and condensed, cold water is made to circulate around the coil. The condensed steam escapes at *w*.

across the stove and dip into a bottle. As the liquid boils, steam escapes through the spout, and on reaching the cold bottle condenses and drops into the bottle as pure water. The impurities remain behind in the kettle. Water freed from im-

purities in this way is called *distilled water*, and the process is called *distillation* (Fig. 23). By this method, the salt water of the ocean may be separated into pure drinking water and salt, and many of the large ocean liners distill from the briny deep all the drinking water used on their ocean voyages.

Commercially, distillation is a very important process. Turpentine, for example, is made by distilling the sap of pine trees. Incisions are cut in the bark of the long-leaf pine trees, and these serve as channels for the escape of crude rosin. This crude liquid is collected in barrels and taken to a distillery, where it is distilled into turpentine and rosin. The turpentine is the product which passes off as vapor, and the rosin is the mass left in the boiler after the distillation of the turpentine.

Evaporation. — If a stopper is removed from a cologne bottle, the contents of the bottle slowly evaporates; if a dish of water is placed out of doors on a hot day, evaporation occurs very rapidly. The liquids which have disappeared from the bottle and the dish have passed into the surrounding air in the form of vapor. Water passes into vapor only with the addition of heat; now the heat necessary for the evaporation of the cologne and water was taken from the air, leaving it slightly cooler. If wet hands are not dried with a towel, but are left to dry by evaporation, heat is taken from the hand in the process, leaving a sensation of coolness. Damp clothing should never be worn, because the moisture in it tends to evaporate at the expense of the bodily heat, and this undue loss of heat from the body produces chills. After a bath the body should be well rubbed, otherwise evaporation occurs at the expense of heat which the body cannot ordinarily afford to lose.

Evaporation is a slow process occurring at all times; it is hastened during the summer, because of the large amount of heat present in the atmosphere. Many large cities make use

of the cooling effect of evaporation to lower the temperature of the air in summer; streets are sprinkled not only to lay the dust, but also to cool the surrounding air by the evaporation of the water.

Some thrifty housewives economize by utilizing the cooling effects of evaporation. Butter, cheese, and other foods sensitive to heat are placed in porous vessels wrapped in wet cloths. Rapid evaporation of the water from the wet cloths keeps the contents of the jars cool, and that without expense other than the muscular energy needed for wetting the cloths frequently.

Clouds, rain, snow, fog, frost, dew. — The heat of the sun causes constant evaporation of the waters of oceans, rivers, streams, and marshes. The water vapor set free by evaporation passes into the air, which becomes charged with vapor or is said to be humid. Constant, unceasing evaporation of our lakes, streams, and pools would mean a steady decrease in the supply of water available for daily use, if the escaped water were all retained by the atmosphere and lost to the earth. But although the escaped vapor mingles with the atmosphere, hovering near the earth's surface, or rising far above the level of the mountains, it does not remain there permanently. When this vapor, which has risen far above the earth, meets a cold wind or is chilled in any way, condensation takes place, and a mass of tiny drops of water or of small particles of snow is formed. These droplets of water and tiny particles of snow when massed together form clouds. When the drops or particles become large enough, they fall as rain or snow, and compensate the earth for the great loss of moisture due to evaporation. When the vapor in the air near the earth meets a cold wind or is chilled in any way it also condenses into droplets. These when massed together form a fog; in fact a fog is a cloud near the surface of the earth. Can you tell what becomes of a fog?

When ice water is poured into a glass, a mist forms on the outside of the glass. This is because the water vapor which comes in contact with the glass is chilled and condenses. Often leaves and grass and sidewalks are so cold that the water vapor in the atmosphere condenses on them, and we say a heavy dew has formed. If the temperature of the air falls to the freezing point while the dew is forming, the vapor is frozen and frost is seen instead of dew.

The daily evaporation of moisture into the atmosphere keeps the atmosphere more or less full of water vapor; but the atmosphere can hold only a definite amount of vapor at a given temperature, and as soon as it contains the maximum amount for that temperature, further evaporation ceases. If clothes are hung out on a damp, murky day, they do not dry, because the air contains all the moisture it can hold, and the moisture in the clothes has no chance to evaporate. When the air contains all the moisture it can hold, it is said to be saturated, and if a slight fall in temperature occurs when the air is saturated, condensation immediately begins in the form of rain, snow, or fog. If, however, the air is not saturated, a fall in temperature may occur without producing precipitation. The temperature at which air is saturated and condensation of water vapor begins is called the *dew point*.

How chills are caused. — The discomfort we feel in an overcrowded room is partly due to an excess of moisture in the air, resulting from the breathing and perspiration of many persons. The air is saturated with vapor and cannot take away the perspiration from our bodies, and our clothing becomes moist and our skin tender. When we leave the crowded "tea" or lecture and pass into the colder, drier outside air, clothes and skin give up their load of moisture through sudden evaporation. But evaporation requires heat! This heat is taken from our bodies, and a chill results.

Proper ventilation eliminates much of the physical danger of social events and fresh, dry air should be constantly admitted to crowded rooms in order to replace the air saturated by the breath and perspiration of the occupants.

Weather forecasts. — When the air is near the saturation point, the weather is oppressive and is said to be very humid. For comfort and health, the air should be about two thirds saturated. The presence of some water vapor in the air is absolutely necessary to animal and plant life. In desert regions where vapor is scarce the air is so dry that throat trouble accompanied by a disagreeable tickling is prevalent; fallen leaves become so dry that they crumble to dust; plants lose their freshness and beauty.

The likelihood of rain or frost is often determined by temperature and humidity. If the air is near saturation and the temperature is falling, it is safe to predict bad weather, because the fall of temperature will probably cause rapid condensation, and hence rain. If, however, the air is not near the saturation point, a fall in temperature will not necessarily produce bad weather.

The measurement of humidity is of far wider importance than the mere forecasting of local weather conditions. The close relation between humidity and health has led many institutions, such as hospitals, schools, and factories, to regulate the humidity of the atmosphere as carefully as they do the temperature. Too great humidity is enervating, and not conducive to either mental or physical exertion; on the other hand, too dry air is equally harmful. In summer the humidity conditions cannot be well regulated, but in winter, when houses are artificially heated, the humidity of a room can be increased by placing pans of water near the registers or on radiators.

Heat needed to melt substances. — If a spoon is placed in a vessel of hot water for a few seconds and then removed,

it will be warmer than before it was placed in the hot water. If a lump of melting ice is placed in the vessel of hot water and then removed, the ice will not be warmer than before, but there will be less of it. The heat of the water has been used in melting the ice, not in changing its temperature.

If, on a bitter cold day, a pail of snow is brought into a warm room and a thermometer is placed in the snow, the temperature rises gradually until 32° F. is reached. Then it becomes stationary, and the snow begins to melt. If the pail is put on the fire, the temperature still remains 32° F., but the snow melts more rapidly. As soon as all the snow is completely melted, however, the temperature begins to rise and rises steadily until the water boils, when it again becomes stationary and remains so during the passage of water into vapor.

We see that heat must be supplied to ice at 0° C., or 32° F., in order to change it into water, and further, that the temperature of the mixture does not rise so long as any ice is present, no matter how much heat is supplied. The amount of heat necessary to melt 1 gram of ice has been measured, and has been found to be 80 calories. It takes 80 times as much heat to melt 1 gram of ice at 0° C. as it does to raise the temperature of 1 gram of water 1° C.

If one steps into the snow above the shoe tops, the legs are immediately chilled. This is because the snow in melting takes heat from the body.

Climate. — Heat must be supplied to ice to melt it. On the other hand, water, in freezing, loses heat, and the amount of heat lost by freezing water is exactly equal to the amount of heat absorbed by melting ice. Because water loses heat when it freezes, the presence of large streams of water greatly influences the climate of a region. In winter the heat from the freezing water keeps the temperature of the surrounding air higher than it would naturally be, and consequently the

cold weather is less severe. In summer water evaporates, heat is taken from the air, and consequently the warm weather is less intense.

Molding of glass and forging of iron. — The fire which is hot enough to melt a lump of ice may not be hot enough to melt an iron poker; on the other hand, it may be sufficiently hot to melt a tin spoon. Different substances melt, or liquefy, at different temperatures; for example, ice melts at 0°C. , and tin at 233°C. , while iron requires the high temperature of 1200°C. Most substances have a definite melting or freezing point which never changes so long as the surrounding conditions remain the same.

But while most substances have a definite melting point, some substances do not. When a glass rod is held in a Bunsen burner, it gradually grows softer and softer, and finally a drop of molten glass falls from the end of the rod into the fire. The glass did not suddenly become a liquid at a definite temperature; instead it softened and gradually changed to a liquid. While glass is in the soft, yielding, pliable state, it is molded into dishes, bottles, and other useful objects, such as lamp shades, globes, etc. (Fig. 24). If glass melted suddenly at a definite temperature, it could not be molded in this way. Iron acts similarly as it begins to melt, and because of this property the blacksmith can shape his horseshoes, and the workman can make his engines and other articles of service to man.

Strange behavior of water. — One has but to remember that bottles of water burst when they freeze, and that ice floats on water like wood, to know that water expands on freezing or on solidifying. A quantity of water which occupies 100 cubic feet of space will, on becoming ice, need 109 cubic feet of space. On a cold winter night the water sometimes freezes in the water pipes, and the pipes burst. Water is very peculiar in expanding on solidification, because most sub-

stances contract on solidifying; gelatin and jelly, for example, contract so much that they shrink from the sides of the dish which contains them.

If water contracted in freezing, ice would be heavier than water and would sink in ponds and lakes as fast as it formed, and our streams and ponds would become masses of solid ice, killing all animal and plant life. But the ice is lighter than

FIG. 24. — Molten glass being rolled into a form suitable for window panes.

water and floats on top, and animals in the water beneath are as free to live and swim as they are in the warm sunny days of summer. The most severe winter cannot freeze a deep lake solid, and in the coldest weather a hole made in the ice will show water beneath the surface. Our ice boats cut and break the ice of the river, and through the water beneath our boats daily ply their way to and fro, independent of winter and its blighting blasts.

While most of us are familiar with the bursting of water pipes on a cold night, few of us realize the influence which freezing water exerts on the character of the land around us.

Water sinks into the ground and, on the approach of winter, freezes, expanding about one tenth of its volume; the expanding ice pushes the earth aside, the force in some cases being sufficient to dislodge even huge rocks. In the early days in New England it was said by the farmers that "rocks grew," because fields cleared of stones in the fall became rock covered with the approach of spring; the rocks and stones hidden underground and unseen in the fall were forced to the surface by the winter's expansion. We have all seen fence posts and bricks pushed out of place because of the heaving of the soil beneath them. Often householders must re-lay their pave-

ments and walks because of the damage done by freezing water.

The most conspicuous effect of the expansive power of freezing water is seen in rocky or mountainous regions (Fig. 25). Water easily finds entrance into cracks and crevices of rocks, where it lodges until frozen; then it expands and acts like a wedge, widening cracks, chiseling off edges, and even breaking rocks asunder. In regions where frequent frosts occur, the destructive action of

FIG. 25. — The destruction caused by freezing water.

water works constant changes in the appearance of the land.

Small cracks and crevices are enlarged, massive rocks are pried up out of position, huge slabs are split off, and particles large and small are forced from the parent rock. The greater part of the débris and rubbish brought down from the mountain slopes by the spring rains owes its origin to the fact that water expands when it freezes.

Heat necessary to dissolve a substance. — It requires heat to dissolve a substance, just as it requires heat to change ice to water. If a handful of common salt is placed in a small cup of water and stirred with a thermometer, the temperature of the mixture falls several degrees. This is just what one would expect, because the heat needed to liquefy the salt must come from somewhere, and naturally it comes from the water, thereby lowering the temperature of the water. We know very well that potatoes cease boiling for an instant if a pinch of salt is thrown into the water; this is because the temperature of the water has been lowered by the amount of heat necessary to dissolve the salt.

Let some snow or chopped ice be placed in a vessel and mixed with one third its weight of coarse salt; if then a small tube of cold water is placed in this mixture, the water in the test tube will soon freeze solid. As soon as the snow and salt are mixed the snow melts and the salt dissolves. The heat necessary for this comes in part from the air and in part from the water in the test tube. The water in the tube loses so much heat that it is changed to ice. But the salt mixture does not freeze, because its freezing point is far below that of pure water. The use of salt and ice in ice-cream freezers is a practical application of this principle. The heat necessary for melting the mixture of salt and ice is taken from the cream, which becomes so cold that it freezes.

CHAPTER IV

BURNING OR OXIDATION

Why things burn. — The heat of our bodies comes from the oxidation of the food we eat; the heat for cooking and for warming our houses comes from coal. The production of heat through the burning of coal, or oil, or gas, or wood, is called combustion. Ordinary combustion cannot occur without the presence of a substance called oxygen, which exists rather abundantly in the air; that is, one fifth of our atmosphere consists of this substance which we call oxygen. We throw open our windows to allow fresh air to enter, and we take walks in order to breathe the pure air into our lungs. What we need for the energy and warmth of our bodies is the oxygen in the air. Whether we burn gas or wood or coal, the heat which is produced comes from the combination of these various substances with oxygen. We open the draft of a stove that it may “draw well”; that it may secure oxygen for burning. We throw a blanket over burning material to smother the fire; to keep oxygen away from it. Burning, or oxidation, is combining with oxygen, and the more oxygen you add to a fire, the hotter the fire burns, and the faster. The effect of oxygen on combustion may be clearly seen by thrusting a smoldering splinter into a jar containing oxygen; the smoldering splinter instantly flares and blazes, while if it is removed from the jar, it again burns quietly.

How to prepare oxygen. — Mix a small quantity of potassium chlorate with an equal amount of manganese dioxide and place the mixture in a test tube. Close the mouth of the tube

with a one-hole rubber stopper in which is fitted a long, narrow tube, and clamp the test tube to an iron support as shown in Figure 26. Fill the trough with water until the shelf is just covered and allow the end of the delivery tube to rest just beneath the hole in the shelf. Fill a medium-sized bottle with water, cover it with a glass plate, invert the bottle in the trough, and then remove the glass plate. Heat the test tube very gently, and when the gas bubbles out of the tube, slip the bottle over the opening in the shelf, so that the tube runs into the bottle. The gas will force out the water and will finally

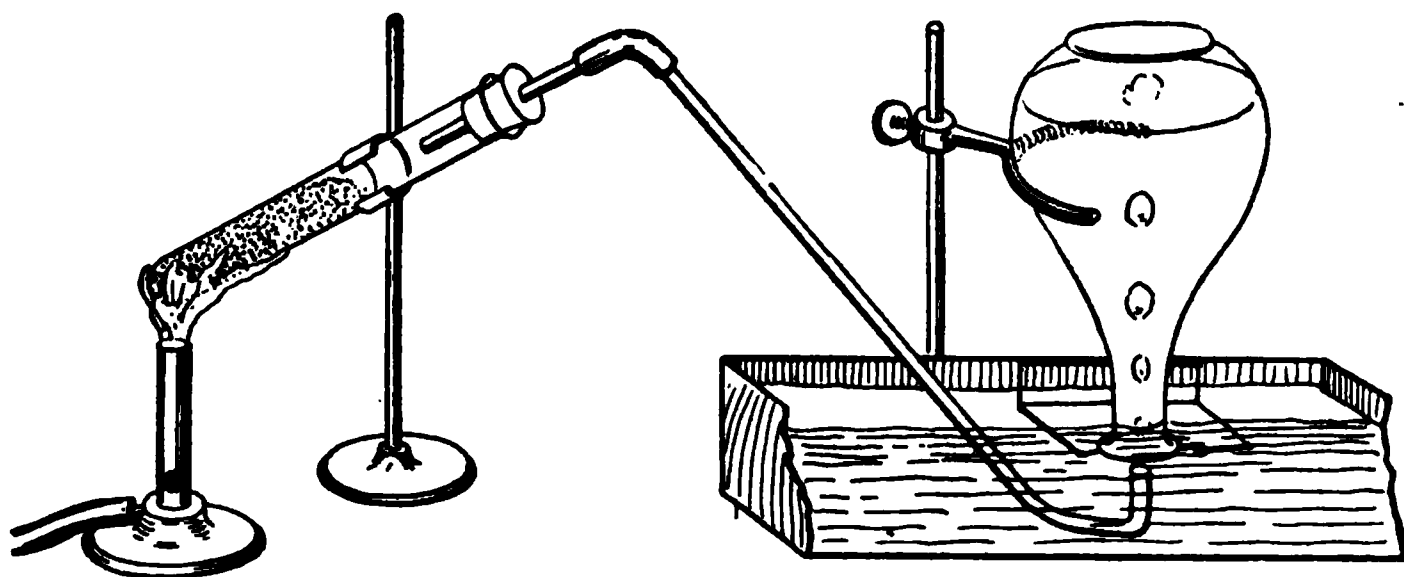


FIG. 26. — Preparing oxygen from potassium chlorate and manganese dioxide.

fill the bottle. When all the water has been forced out, slip the glass plate under the mouth of the bottle and remove the bottle from the trough. The gas in the bottle is oxygen.

Everywhere in a large city or in a small village, smoke is seen, indicating the presence of fire; hence there must exist a large supply of oxygen to keep all the fires alive. The supply of oxygen needed for the fires of the world comes largely from the atmosphere.

Matches. — Material is ordinarily set on fire by matches, thin strips of wood tipped with sulphur or phosphorus, or both. Phosphorus can unite with oxygen at a fairly low temperature, and when phosphorus is rubbed against a rough surface the

friction produced raises the temperature of the phosphorus to a point where it can combine with oxygen. The burning phosphorus kindles the wood of the match, and from the burning match the fire is kindled. But matches have been in use less than a hundred years! Primitive man kindled his camp fire by rubbing pieces of dry wood together until they took fire, and this method is said to be used among some isolated distant tribes at the present time. If you want to convince yourself that friction produces heat, rub a cent vigorously against your coat and notice how warm the cent becomes. A later and easier way was to strike flint and steel together and to catch the spark thus produced on tinder or dry fungus. The burning tinder was then put into a closed vessel, where it smoldered quietly until it was needed for starting a fresh fire. Within the memory of some persons now living, the tinder box was a valuable asset to the home, particularly in the pioneer regions of the West. If any accident happened to the tinder box, there was great consternation in the household, because in order to start a new fire, the primitive method had to be resorted to, or a long journey had to be made to the nearest neighbor for the loan of a tinder box.

Safety matches. — Ordinary phosphorus, while excellent as a fire-producing material, is dangerously poisonous, and those to whom the dipping of wooden strips into phosphorus is a daily occupation suffer from a terrible disease which usually attacks the teeth and bones of the jaw. The teeth rot and fall out, abscesses form, and bones and flesh begin to decay. The only way to prevent the spread of the disease is to remove the affected bone, and in some instances it has been necessary to remove the entire jaw. Then, too, matches made of yellow or white phosphorus ignite easily, and, when rubbed against any rough surface are apt to take fire. Many destructive fires have been started by the accidental friction of such matches against rough surfaces.

For these reasons the introduction of the so-called safety

match was an important event. When common phosphorus, in the dangerous and easily ignited form, is heated in a closed vessel to about 250° C., it gradually changes to a harmless red mass. The red phosphorus is not only harmless, but it is difficult to ignite, and, in order to be ignited by friction, must be rubbed on a surface rich in oxygen. The head of a safety match is coated with a mixture of glue and oxygen-containing compounds; the surface on which the match is to be rubbed is coated with a mixture of red phosphorus and glue, to which finely powdered glass is sometimes added in order to increase the friction. Unless the head of the match is rubbed on the prepared phosphorus coating, ignition does not occur, and accidental fires are avoided.

Various kinds of safety matches have been manufactured in the last few years, but they are somewhat more expensive than the ordinary form, and manufacturers are reluctant to substitute them for the cheaper matches. Some foreign countries, such as Switzerland, prohibit the sale of the dangerous type, and it is hoped that the United States will soon follow the lead of these countries in requiring the sale of safety matches only.

Some unfamiliar forms of burning. — While most of us think of burning as a process in which flames and smoke occur, there are in reality many modes of burning accompanied by neither flame nor smoke. Iron might be said to burn when it rusts, because it slowly combines with the oxygen of the air and new substances are formed. When the air is dry, iron does not unite with oxygen, but when moisture is present, the iron unites with the oxygen and turns into iron rust. The burning is slow and unaccompanied by the fire and smoke so familiar to us, but the process is none the less burning, or combination with oxygen. Burning which is not accompanied by any of the appearances of ordinary burning is known as oxidation.

The tendency of iron to rust lessens its efficiency and value,

and many devices have been introduced to prevent rusting. A coating of paint or varnish is sometimes applied to iron in order to prevent contact with air. The galvanizing of iron is another attempt to secure the same result; in this process iron is dipped into molten zinc, thereby acquiring a coating of zinc, and forming what is known as galvanized iron. Zinc does not combine with oxygen under ordinary circumstances, and hence galvanized iron does not rust.

Decay is a process of oxidation! The tree which rots slowly away is undergoing oxidation, and the result of the slow burning is the decomposed matter which we see, and the invisible gases which pass into the atmosphere. The log which blazes on our hearth gives out sufficient heat to warm us; the log which decays in the forest gives out an equivalent amount of heat, but the heat is evolved so slowly that we are not conscious of it. Burning accompanied by a blaze and intense heat is a rapid process; burning unaccompanied by fire and appreciable heat is a slow, gradual process, requiring days, weeks, and even years for its completion.

Still another form of oxidation occurs daily in the human body! The human body is an engine whose fuel is food; the burning of food in the body furnishes the heat necessary for bodily warmth and the energy required for thought and action. Oxygen is essential to burning, and the food fires within the body are kept alive by the oxygen taken into the body at every breath by the lungs. We see now one reason for an abundance of fresh air in daily life.

How to breathe. — Air, which is essential to life and health, should enter the body through the nose and *not through the mouth*. The peculiar nature and arrangement of the membranes of the nose enable the nostrils to clean, to warm, and to moisten the air which passes through them to the lungs. Floating around in the atmosphere are dust particles which ought

not to get into the lungs. The nose is provided with small hairs and a moist inner membrane which serve as filters in removing solid particles from the air, and in thus purifying it before its entrance into the lungs.

In the immediate neighborhood of three Philadelphia high schools, having an approximate enrollment of over 8000 pupils, is a huge manufacturing plant which day and night pours forth grimy smoke and soot into the atmosphere which supplies oxygen to this vast group of young people. If the vital importance of nose breathing is impressed upon these young people, the harmful effect of the foul air may be greatly lessened, the smoke particles and germs being held back by the nose filters and never reaching the lungs. If, however, this principle of hygiene is not brought to their attention, the dangerous habit of breathing through an open, or a partially open, mouth will continue, and objectionable matter will pass through the mouth and find a lodging place in the lungs.

There is another very important reason why nose breathing is preferable to mouth breathing. The temperature of the human body is approximately 98° F., and the air which enters the lungs should not be far below this temperature. If air reaches the lungs through the nose, its journey is relatively long and slow, and there is opportunity for it to be warmed before it reaches the lungs. If, on the other hand, air passes to the lungs by way of the mouth, the warming process is brief and insufficient, and the lungs suffer in consequence. Naturally, the gravest danger is in winter.

Cause of mouth breathing. — Some people find it difficult to breathe through the nostrils on account of growths, called adenoids. If you have a tendency toward mouth breathing (Fig. 27), let a physician examine your nose and throat.

Adenoids not only obstruct breathing and weaken the whole system through lack of adequate air, but they also press upon

the blood vessels and nerves of the head and interfere with normal brain development. Moreover they interfere in many cases with the hearing, and in general hinder bodily growth.

The removal of adenoids is simple, and carries with it only temporary pain and no danger. Some physicians claim that the growths disappear in later years, but even if that is true, the physical and mental development of earlier years is lost, and the person is backward in the struggle for life and achievement.

FIG. 27 — Intelligent expression is often lacking in children with adenoid growths.

How to build a fire. — Substances differ greatly as to the ease with which they

burn or unite with oxygen. For this reason, we put light materials, like shavings, chips, and paper, on the grate, twisting the latter and arranging it so that air (oxygen in the air) can reach a large surface; upon this we place small sticks of wood, piling them across each other so as to allow entrance for the oxygen; and finally upon this we place our hard wood or coal.

The coal and the large sticks cannot be kindled with a match, but the paper and shavings can, and these in burning heat the large sticks until they take fire and in turn kindle the coal.

Spontaneous combustion. — We often hear of fires "starting themselves," and sometimes the statement is true. If a pile of oily rags is allowed to stand for a time, the oily matter begins to combine slowly with oxygen, and as a result gives off heat. The heat thus given off is at first insufficient to

kindle a fire; but as the heat is retained and accumulated, the temperature rises, and finally the kindling point is reached and the whole mass bursts into flames. For safety's sake, all oily cloths should be burned or kept in metal vessels.

The treatment of burns. — In spite of great caution, burns from fires, steam, or hot water do sometimes occur, and it is well to know how to relieve the suffering caused by them and how to treat the injury in order to secure rapid healing.

Burns are dangerous because they destroy skin and open up an entrance into the body for disease germs; and also because they lay bare nerve tissue which thereby becomes irritated and causes a shock to the system.

In mild burns, where the skin is not broken but is merely reddened, an application of moist baking soda brings immediate relief. If this substance is not available, flour paste, lard, sweet oil, or vaseline may be used.

In more severe burns, where blisters are formed, the blisters should be punctured with a sharp, sterilized needle and allowed to discharge their watery contents before the above remedies are applied.

In burns severe enough to destroy the skin, disinfection of the open wound with weak carbolic acid or hydrogen peroxide is very necessary. After this has been done, a soft cloth soaked in a solution of linseed oil and limewater should be applied and the whole bandaged. In such a case, it is important not to use cotton batting, since this sticks to the rough surface and causes pain when removed.

Carbon dioxide. *A product of burning.* — When any fuel, such as coal, gas, oil, or wood, burns, it sends forth gases into the surrounding atmosphere. These gases, like air, are invisible, and were unknown for a long time. The chief gas formed by a burning substance is called carbon dioxide (CO_2) because it is composed of one part of carbon and two parts

of oxygen. This gas is the most widely distributed gaseous compound of the entire world; it is found in the ocean depths and on the mountain heights, in brilliantly lighted rooms, and most abundantly in manufacturing towns where factory chimneys constantly pour forth hot gases and smoke.

Wood and coal, and in fact all animal and vegetable matter, contain carbon, and when these substances burn or decay, the carbon in them unites with oxygen and forms carbon dioxide.

The food which we eat is either animal or vegetable, and it is made ready for bodily use by a slow oxidizing process within the body. Carbon dioxide accompanies this bodily burning of food just as it accompanies the fires with which we are more familiar. The carbon dioxide thus produced within the body escapes into the atmosphere with the breath.

The source of carbon dioxide is practically inexhaustible, coming as it does from stove, furnace, and candle, and from every breath of a living organism.

Ventilation. — Where many people are gathered together in badly ventilated rooms, the air soon becomes foul and causes headache and weariness. This discomfort is due less to carbon dioxide than to high temperature, high humidity (see page 43)

FIG. 28. — Removing bad air from a room.

and disagreeable odors from hot perspiring bodies and soiled clothes.

In a well-planned building, gentle but steady fresh air currents lower the temperature and the humidity, blow away the odors, and keep the building well ventilated and comfortable. An auditorium whose ventilating system is planned for 500 people should never admit 800 people.

In houses which have no ventilating system, the air should be kept fresh by intelligent action in the opening of doors and windows. Since relatively few houses are equipped with a satisfactory system, the following suggestions relative to intelligent ventilation are offered.

1. Ventilate on the sheltered side of the house. If the wind is blowing from the north, open south windows.

2. Avoid drafts in ventilation. Ventilate by lowering windows from the top rather than by raising them at the bottom, unless a window board is used to break the force of the incoming air (Fig. 29).

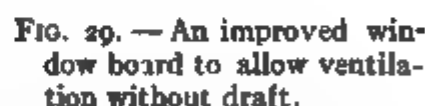


FIG. 29. — An improved window board to allow ventilation without draft.

What becomes of the carbon dioxide. — Although carbon dioxide is constantly being produced as a result of burning, it does not accumulate in the atmosphere. Normal outdoor air contains only about $\frac{1}{100}$ of one per cent of it. What, then, becomes of the large quantities of carbon dioxide that result from combustion and oxidation? Plants absorb it from the atmosphere through their leaves, and by a wonderful process break it up into oxygen and carbon. They reject the oxygen, which passes back to the air, but they retain the carbon, which becomes a part of their structure. Plants thus serve

to keep the atmosphere free from an excess of carbon dioxide and in addition, they furnish oxygen to the atmosphere.

This can be shown by a simple experiment. Place a glass funnel over a plant growing in a sunny aquarium. Then fill a test tube with water and invert it over the funnel as shown in Figure 30. Bubbles of gas slowly make their way up the funnel and force some of the water out of the test tube. If the test tube is removed and a smoldering splinter is thrust into the gas, the splinter bursts into flame, showing that oxygen is present. The oxygen has come from the plant. Experiments also prove that plants absorb carbon dioxide. Plants serve a twofold good; they remove the injurious gas, carbon dioxide, and they set free the desired gas, oxygen.

FIG. 30. — Plants give off oxygen.

How to obtain carbon dioxide. — There are several ways in which carbon dioxide can be produced commercially, but for laboratory use, the simplest way is to mix powdered marble, or chalk, and hydrochloric acid in a test tube, and to collect the effervescing gas as shown in Figure 31. The escaping carbon dioxide is heavier than air, and hence it settles in *A*. The substance which is left in the test tube after the gas has

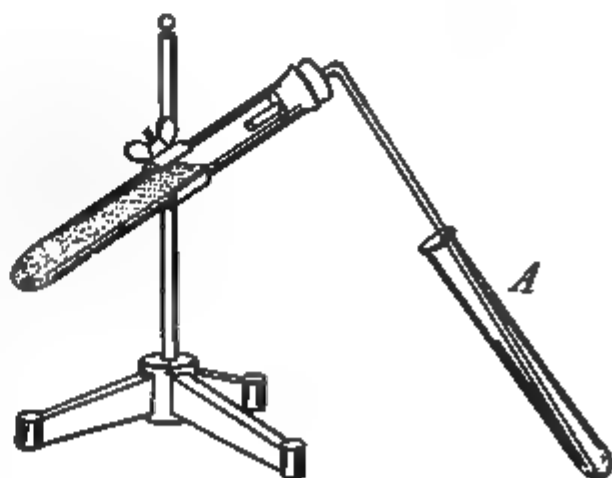


FIG. 31. — Making carbon dioxide from marble and hydrochloric acid.

passed off is a solution of a salt and water. From a mixture of hydrochloric acid and marble are obtained a salt, water, and carbon dioxide.

A commercial use of carbon dioxide.—If a lighted splinter is thrust into a test tube containing carbon dioxide, it is promptly extinguished, because carbon dioxide cannot support combustion; if a stream of carbon dioxide and water falls upon a fire, it acts like a blanket, covering the flames and extinguishing them. The value of a fire extinguisher depends upon the amount of carbon dioxide and water which it can furnish. One form of fire extinguisher consists of a metal case (Fig. 32) containing a solution of bicarbonate of soda and a glass vessel half full of strong sulphuric acid. As long as the extinguisher is in an upright position, these substances are kept separate, but when the extinguisher is inverted, the acid escapes from the bottle, and mixes with the soda solution. The mingling liquids interact and liberate carbon dioxide. A part of the gas thus liberated dissolves in the water of the soda solution and escapes from the tube with the outflowing liquid.

Carbon. — Although carbon dioxide is very injurious to health, both of the sub-

FIG. 32. — Inside view of a fire extinguisher.

stances of which it is composed are necessary to life. Our bodies, our bones and flesh in particular, are partly carbon, and every animal, no matter how small or insignificant, contains some carbon; while the plants around us, the trees, the grass, the flowers, contain a large quantity of it.

Carbon plays an important and varied rôle in our life, and in some one of its many forms, enters into the composition of most of the substances which are of service and value to us. The food we eat, the clothes we wear, the wood and coal we burn, the marble we employ in building, the indispensable soap, and the ornamental diamond, all contain carbon in some form.

Charcoal. — One of the most valuable forms of carbon is charcoal; valuable not in the sense that it costs hundreds of dollars, but in the more vital sense, that its use adds to the cleanliness, comfort, and health of man.

The foul, bad-smelling gases which arise from sewers can be prevented from escaping and passing to streets and buildings by placing charcoal filters at the sewer exits. Charcoal is porous and absorbs foul gases, and keeps the region surrounding sewers sweet and clean and free of odor. Good housekeepers drop small bits of charcoal into vases of flowers to prevent discoloration of the water and the odor of decaying stems.

If impure water filters through charcoal, it emerges pure, having left its impurities in the pores of the charcoal. Many household filters of drinking water are made of charcoal. But such a device may be a source of disease instead of a prevention of it, unless the filter is regularly cleaned or renewed.

Commercially, charcoal is used on a large scale in the refining of sugars, sirups, and oils. Sugar, whether it comes from the maple tree, or the sugar cane, or the beet, is dark in color. It may be whitened by passage through filters of finely pulverized charcoal. Cider and vinegar may likewise be cleared by passage through charcoal.

The value of charcoal as a purifier is very great, whether we consider it a deodorizer, as in the case of the sewage, or a decolorizer, as in the case of the refineries, or as an agent in purifying drinking water.

How charcoal is made. — Charcoal may be made by heating wood in an oven to which air does not have free access. The absence of air prevents ordinary combustion, nevertheless the intense heat affects the wood and changes it into new substances, one of which is charcoal.

The wood which smolders on the hearth and in the stove is charcoal in the making. Formerly wood was piled in heaps (Fig. 33), covered with sod or sand to prevent access of oxygen, and then set on fire; the smoldering wood,

FIG. 33. — Making charcoal.

cut off from an adequate supply of air, was slowly transformed into charcoal. Later, crude earthen receptacles, or charcoal kilns, were built in rock or hillside and the burning wood was smothered in these. Scattered over the country one still finds isolated charcoal kilns, or crude earthen receptacles in which wood thus deprived of air was allowed to smolder and form charcoal. To-day charcoal is made commercially by piling wood on steel cars and then pushing the cars into strong walled chambers. The chambers are then closed to keep out the air, and are heated to a high temperature. The intense heat transforms the wood into charcoal in a few hours. A student can make in the laboratory sufficient charcoal for art lessons by heating in an earthen vessel wood buried in sand.

A form of charcoal known as animal charcoal, or bone black, is obtained from the charred remains of animals instead of

plants, and may be prepared by burning bones and animal refuse as in the case of wood.

Destructive distillation. — When wood is burned without sufficient air, it is changed into soft brittle charcoal, a substance

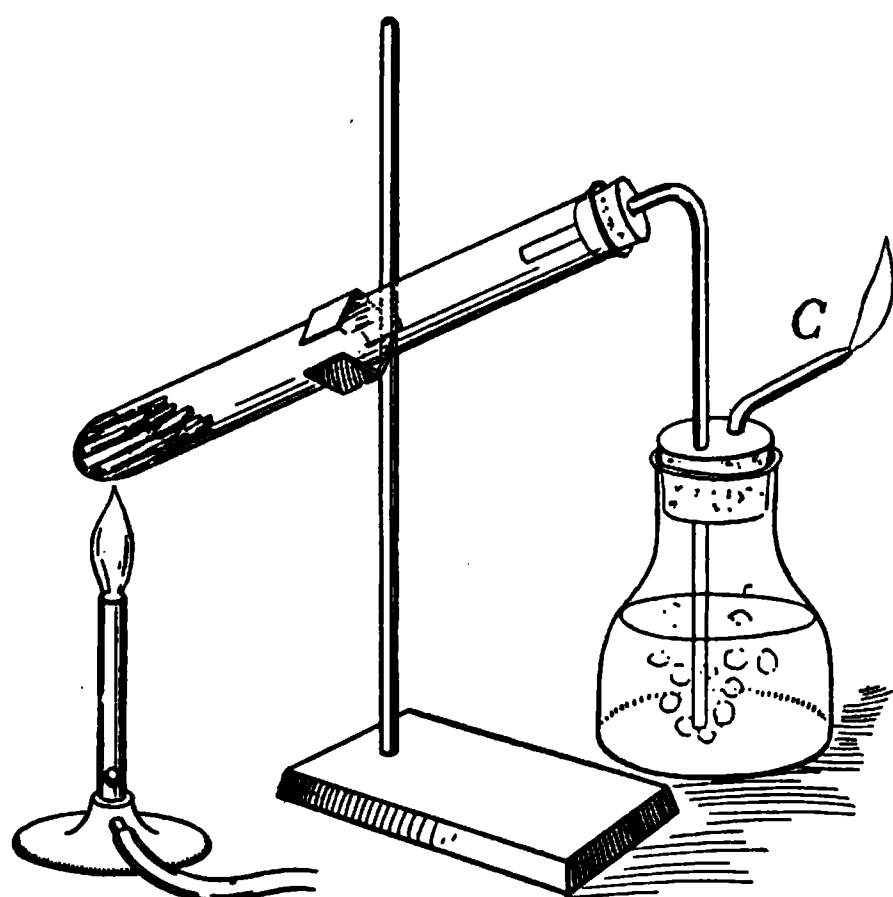


FIG. 34. — Destructive distillation of wood.

very different from wood and only one fourth as heavy. Because charcoal is unlike wood and because it weighs less, wood in turning to charcoal must lose some of the substances of which it is composed. We can prove this by putting dry wood shavings in a strong test tube connected with a bottle of water as shown in Figure 34. Heating the tube gently and slowly

we notice that a change takes place in the wood, and if we bring a lighted match to C while the wood is being heated, a small flame appears. Evidently a combustible gas is given off from the wood. It is not easy in the ordinary school laboratory to determine the other substances given off from the wood, but it has been done by experts, who have found wood alcohol, wood tar, acetic acid, and other commercial substances.

Wood heated without sufficient air is broken up into a number of simpler substances. The process by which complex substances are thus broken up into simpler substances is called *destructive distillation*.

Most of the substances given off by wood burning without air are valuable commercially. Wood alcohol serves as a fuel, and is largely used to dissolve and thin varnishes, oils, and

resins. Wood tar is an ingredient of lubricating oils and axle greases. Acetic acid is used in the preparation of certain dyes and medicines, and in the manufacture of vinegar. In the old-fashioned method of charcoal making, these products were lost; in the modern method they are collected and used.

Matter and energy. — When wood is burned in the air, a small pile of ashes is left, and we think of the bulk of the wood as destroyed. It is true that we have less matter that is available for use or that is visible to sight, but, nevertheless, no matter has been destroyed. The matter of which the wood is composed has merely changed its character; some of it is in the condition of ashes, and some of it in the condition of invisible gases, such as carbon dioxide, but none of it has been destroyed. It is a principle of science that matter can neither be destroyed nor created; it can only be changed, or transformed, and it is our business to see that we do not heedlessly transform it into substances which are valueless to us and our descendants; as, for example, when our magnificent forests are recklessly wasted. The smoke, gases, and ashes left in the path of a raging forest fire are no compensation to us for the valuable timber destroyed. The sum total of matter has not been changed, but the amount of matter which man can use has been greatly lessened.

The principle just stated forms one of the fundamental laws of science, called the law of the *conservation of matter*.

A similar law holds for energy. We can transform electric energy into the motion of trolley cars, or we can make use of the energy of streams to turn the wheels of our mills, but in all these cases we are transforming, not creating, energy.

When a ball is fired from a rifle, most of the energy of the gunpowder is utilized in motion, but some is dissipated in producing a flash and a report, and in heat. The energy of the gunpowder has been scattered, but the sum of the various

forms of energy is equal to the energy originally stored away in the powder. The better the gun is, the less will be the energy dissipated in smoke and heat and noise.

Chemical action as a source of heat. — Heat is a strong factor in bringing about chemical changes. Manganese dioxide and potassium chlorate do not yield oxygen unless they are heated; wood does not change to charcoal unless it is heated. But some chemical changes take place without strong heat; bicycles and keys rust at ordinary temperature, and carpets and draperies fade and lose their brilliant hues.

Heat usually assists chemical action, and it is equally true that chemical action sometimes produces heat. When hydrochloric acid is poured upon marble, the chemical change which sets free carbon dioxide also sets free heat. You can easily test this for yourself by holding your hand on a bottle in which acid and marble are mixed. The heat produced by the chemical action warms the bottle and the hand. The heat of chemical change can be seen by us at any place where a building is being erected or where alterations are being made. A laborer makes mortar by mixing water, lime, and sand, and the mixture is often so hot that it steams. Buildings in which lime is stored frequently take fire, and the transportation of lime in ordinary vessels is very dangerous. If rain leaks in upon the lime, or if water reaches it in any way, chemical change occurs and the heat produced is frequently sufficient to set fire to the building or vessel. The only safe way to transport lime is to put it in sealed metal containers through which water cannot soak or leak.

CHAPTER V

FOOD

The body as a machine. — Wholesome food and fresh air are necessary for a healthy body. Many housewives, through ignorance, supply to their hard-working husbands and their growing sons and daughters food which satisfies the appetite, but which does not give to the body the substances needed for daily work and growth. Some foods, such as lettuce, cucumbers, and watermelons, make proper and satisfactory changes in diet, but are not strength giving. Other foods, like peas and beans, not only satisfy the appetite but supply to the body abundant nourishment, and many immigrants live cheaply and well with beans and bread as their main diet.

It is important that the value of different foods as heat producers be known definitely; and just as the yard measures length and the pound measures weight, the Calorie¹ is used to measure the amount of heat which a food is capable of furnishing to the body. Our bodies are human machines, and, like all other machines, require fuel for their maintenance. The fuel supplied to an engine is not all available for pulling the cars; a large portion of it is lost in smoke, and another portion is wasted as ashes. So it is with the fuel that runs the body. The food we eat is not all available for heat and work, much of it being as useless to us as are smoke and ashes to an engine. The most economical foods are those which do the most for us with the least possible waste.

¹ The Calorie equals 1000 calories, the amount of heat required to raise the temperature of 1 kilogram (1000 grams) of water 1° C.

Fuel value. — By fuel value is meant the capacity foods have for yielding heat and energy to the body. The fuel value of the foods we eat is so important a factor that physicians, nurses, and dietitians acquaint themselves with the fuel values of the important food substances. The life or death of a patient may be determined by the patient's diet, and the working and earning power of a father depends largely upon his three meals. An ounce of fat, whether it is the fat of meat or the fat of olive oil, or the fat of any other food, produces in the body two and a quarter times as much heat as an ounce of starch. Of the vegetables, beans provide the greatest heat and energy at the least cost, and to a large extent may be substituted for meat. It is not uncommon to find an outdoor laborer consuming one pound of beans per day, and taking meat only on "high days and holidays."

The fuel value of a food is determined by means of the bomb calorimeter (Fig. 35). The food substance is put into a chamber *A* and ignited, and the heat of the burning substance raises the temperature of the water in the surrounding vessel. If 2 kilograms of water are in

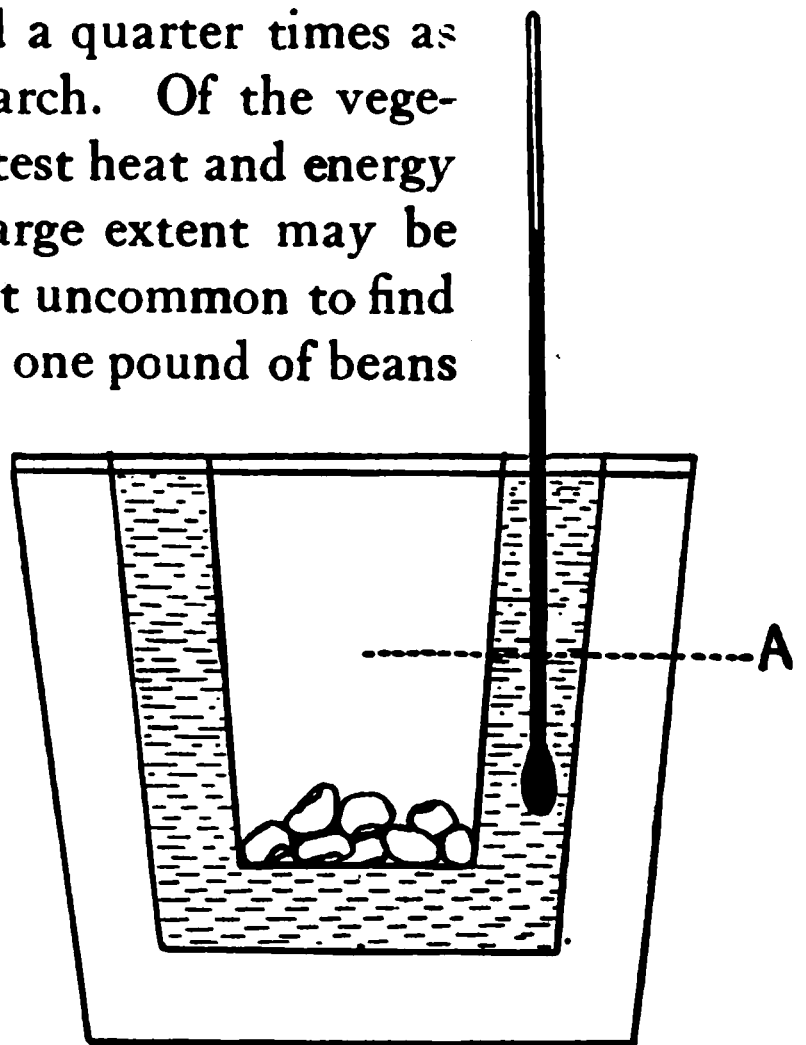


FIG. 35. — Diagram of a bomb calorimeter by which the value of food can be estimated.

the vessel, and the temperature of the water is raised 50° C., the number of Calories produced by the substance is 100, and the fuel value of it is 100 Calories. From this the fuel value of one pound or one quart of the substance can be determined, and the food substance furnishes the body with that

number of heat units, providing all of the pound of food is digested.

Our bodies. — Somewhat as a house is composed of a group of bricks, or a sand heap of grains of sand, the human body is composed of small divisions called cells. Ordinarily we cannot see these cells because of their minuteness, but if we examine a piece of skin, or a hair of the head, or a tiny sliver of bone under the microscope, we see that each of these is composed of a group of different cells. A merchant, watchful about the fineness of the wool which he is purchasing, counts with his lens the number of threads to the inch; a physician, when he wishes, can, with the aid of the microscope, examine the cells in a muscle, or in a piece of fat, or in a nerve fiber. Not only is the human body composed of cells, but so also are the bodies of all animals, from the tiny gnat which annoys us, and the fly which buzzes around us, to the mammoth creatures of the tropics. The different cells do the work of the body; the bone cells build up the skeleton, the nail cells form the finger and toe nails, the lung cells take care of breathing, the muscle cells produce motion, and the brain cells are responsible for thought.

Why we eat so much. — The cells of the body are constantly, day by day, minute by minute, breaking down and needing repair, are constantly requiring replacement by new cells, and, in the child, are continually increasing in number. The repair of an ordinary machine, an engine, for example, is made at the expense of money, but the repair and replacement of our human cell machinery are accomplished at the expense of food. More than one third of all the food we eat goes to maintain the body cells, and to keep them in good order. It is for this reason that we consume a large quantity of food. If all the food we eat were utilized for energy, the housewife could cook less, and the housefather could save money on grocers' and butchers' bills. If you burn a ton of coal in an

engine, the energy of the coal is used to run the engine, but if the engine were like the human body, one third of the ton would be used in keeping walls, shafts, wheels, and belts of the engine in order, and only two thirds would go toward running the engine.

When an engine is not working, fuel is not consumed, but the body requires food for mere existence, regardless of whether it does active work or not. When we work, the cells break down more quickly, and the need for repair is greater than when we are at rest, and hence there is need of a larger amount of food. But whether we work or not, food is necessary!

The different foods. — The body is very exacting in its demands, requiring certain definite foods for the formation and maintenance of its cells, and other foods, equally definite, but of different character, for heat and energy. Our diet therefore must contain foods of high fuel value, and foods of cell-forming power.

Although the foods which we eat are of widely different character, such as fruits, vegetables, cereals, oils, meats, eggs, milk, cheese, etc., they can be put into three great classes: carbohydrates, fats, and proteins.

The carbohydrates. — Corn, wheat, rye, in fact all cereals and grains, potatoes, and most vegetables are rich in carbohydrates, as are also sugar, molasses, honey, and maple sirup. The foods of the first group are valuable because of the starch they contain; for example, corn starch, wheat starch, potato starch. The substances of the second group are valuable because of the sugar they contain. In the sirups there is a considerable quantity of sugar, while in some fruits it is present in more or less dilute form. Sweet peaches, apples, grapes contain a moderate amount of sugar; watermelons, pears, etc., contain less. Most of our carbohydrates are of plant origin, being either cereals, sirups, vegetables, or fruits.

Carbohydrates, whether of the starch group or of the sugar group, are composed chiefly of three elements: carbon, hydrogen, and oxygen; they are therefore combustible, and are great energy producers. On the other hand, they are worthless for cell growth and repair, and if we limited our diet to carbohydrates, we should be like a man who had fuel but no engine capable of using it.

The fats. — The best-known fats are butter, lard, olive oil and the fats of meats, cheese, and chocolate. When we test fats for fuel values by means of a calorimeter, we find that they yield twice as much heat as the carbohydrates (Fig. 36), but that they burn out more quickly. Dwellers in cold climates must constantly eat large quantities of fatty foods if they are to keep their bodies warm and survive the extreme cold. Cod liver oil is an excellent food medicine, and if taken in winter serves to warm the body and to protect it against the rigors of cold weather. The average person avoids fatty foods in summer, knowing from experience that rich foods make him warm and uncomfortable. The harder we work and the colder the weather, the more fatty food do we require; it is said that a lumberman doing heavy out-of-door work in cold climates needs three times as much food as a city clerk.

Most of our fats, like lard, butter, and cheese, are of animal origin; some of them, however, like olive oil, peanut butter, and coconut oil, are of plant origin.

The proteins. — The proteins are the building foods, furnishing muscle, bone, skin cells, etc., and supplying blood and other bodily fluids. The best-known proteins are white of egg, curd of milk, and lean of fish and meat. Most of our proteins are



FIG. 36. — *a* is the amount of fat necessary to make one Calorie; *b* is the amount of sugar or protein necessary to make one Calorie.

of animal origin, but some protein material is also found in the vegetable world; peas and beans have an abundant supply of this substance, and nuts are likewise rich in it. This class of foods contains carbon, oxygen, and hydrogen, and in addition two substances not found in carbohydrates or fats — namely, sulphur and nitrogen. The living cells of the body always contain nitrogen, and old cells cannot be repaired, and additional cells cannot be formed, unless nitrogen is supplied to them. Proteins always contain nitrogen, and hence they are frequently spoken of as the nitrogenous foods. Since proteins contain all the elements found in the two other classes of foods, they are able to contribute, if necessary, to the store of bodily energy; but their main function is up-building, and the diet should be chosen so that the protein does not have a double task. It has been estimated that 300,000,000 blood cells alone need daily repair or renewal. When we consider that the blood is but one part of the body, and that all organs and fluids have corresponding requirements, we realize how vast is the work to be done by the protein. For an average man four ounces of dry protein matter daily suffice to keep the cells in normal condition.

Mineral matter.—Mineral matter, such as iron, phosphate, calcium, and magnesium, is needed by the body for teeth, bones, and nails, and for cells in general. Iron is used by the blood cells which carry oxygen; calcium and phosphorus are used in the building up of bones; and phosphorus and sodium occur in every cell and are necessary to cell growth and activity. Mineral matter is an essential part of the diet. Usually mineral matter is found in greatest abundance in plant food of low fuel value, such as lettuce, water cress, spinach, cucumbers, cabbage, and tomatoes. Animal foods contain very little mineral matter, and hence a mixed diet of plant and animal foods is best. The following table shows the value of plant foods in supplying the body with mineral matter.

FOODS RICH IN MINERAL MATTER

IRON	PHOSPHORUS	POTASSIUM	SODIUM	CALCIUM
Prunes Spinach Raisins Turnips Navy beans Cabbage	Prunes Turnips Parsnips Peanuts Navy beans Peas	Lentils Figs Molasses Rhubarb Parsnips Apples	Prunes Spinach Carrots Celery Cauliflower Radishes	Prunes Oatmeal Carrots Beans Pineapple Peanuts

Water. — Water neither builds up tissue nor furnishes heat and energy to the body, but it is nevertheless indispensable to health. It helps to move food along the alimentary canal, it helps to dissolve food, it distributes food to all parts of the body, and it assists the removal of waste matter.

Since the digestive juices which act upon food, the blood which carries food, and the urine which throws off waste matter through the kidneys, contain a large proportion of water, it is necessary that we drink large quantities of water daily. Bones and muscle also contain water; in fact, about two thirds of the entire weight of the body is water. No organ of the body is independent of water; without it blood could not circulate and distribute food; muscles could not contract and relax because they would be hard and stiff; the skin could not throw off waste matter as perspiration; the kidneys could not discharge poisonous substances by means of urine; the bowels could not eject undigested substances because they would be hard and dry and unable to move. The constant replenishing of this large quantity of water is essential to life, and hence a plentiful supply of it should be taken daily.

Some of the water which the body needs is obtained from foods, particularly from fruits and vegetables; asparagus and tomatoes have over 90 per cent water, most fruits are more

than three fourths water, and meats are fully one half water; even bread, which contains as little water as any food, is about one third water (Fig. 37). But although all foods contain some water, the supply which they yield is too meager to supply bodily needs, and it should be daily supplemented by five or six glasses of good drinking water.

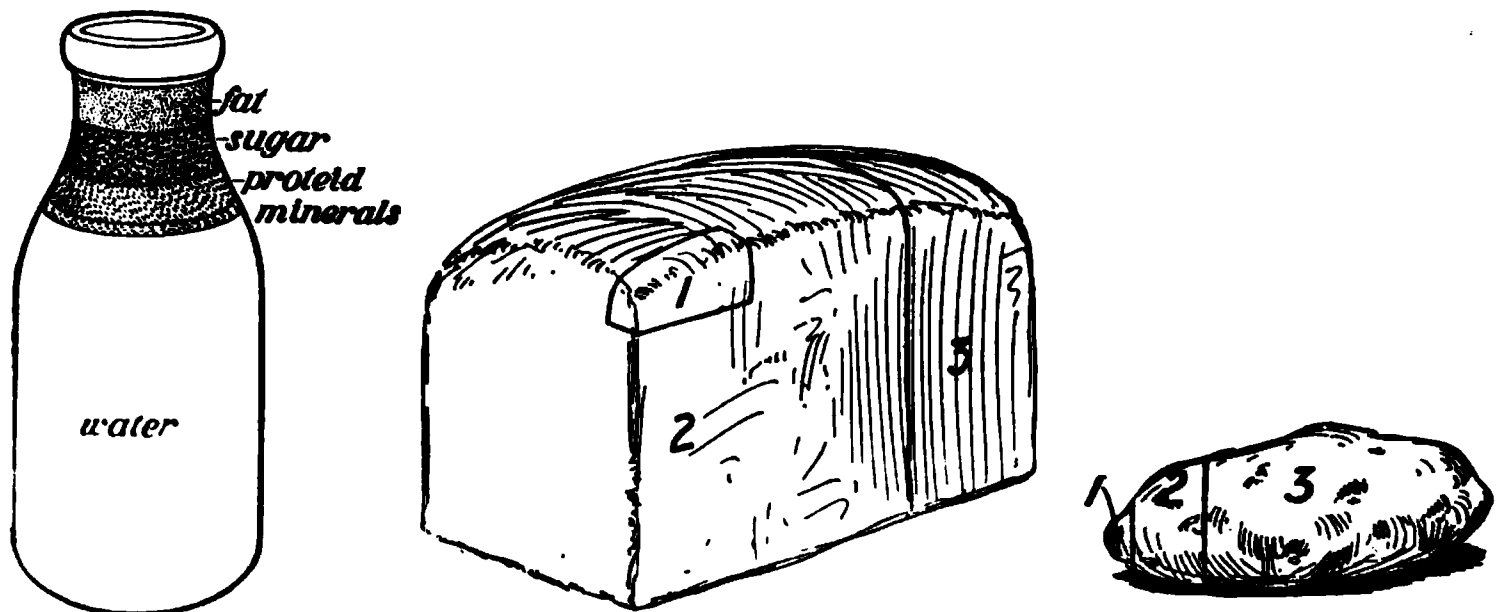


FIG. 37. — Diagram showing the composition of milk, of bread, and of a potato :
1, mineral matter ; 2, food ; 3, water.

How much should we eat. — The amount of food we require depends upon how hard we work. The harder we work, the quicker our cells wear out, and the more proteins we need to keep them in repair; the harder we work, the more muscular energy we use up, and the more carbohydrates we need to supply new energy for work. The amount of food we require depends upon the temperature of the place in which we live; in warm Florida, for example, we require less food than in cold Maine, and in summer we require less food than in winter. The amount of food necessary to keep us active and in good health depends upon what we do and where we live; a stenographer who works in a well heated room and has no heavy muscular work requires less food than a lumberman who does heavy muscular out-of-door work in a cold climate. By experiment it has been proved that a city clerk needs only about one third as much food as a

Canadian lumberman. The *average* adult worker ought to have every day sufficient food to furnish 3000 Calories of energy; a growing boy of 15 to 16 years ought to have at least 2700 Calories, and a girl of the same age 2400 Calories.

JAN. 17, 1915	PROTEINS	FATS	CARBOHY- DRATES
<i>Breakfast</i>			
Oatmeal	38.00	36.00	152.00
Apple	2.28	5.06	88.92
Egg	72.96	126.5	—
Milk	21.66	60.72	34.2
Butter	16.96	78.43	2.3
Bread — 2 servings	41.04	15.18	243.96
<i>Lunch</i>			
2 Ham sandwiches			
Bread	41.04	15.18	243.96
Ham	55.82	131.80	—
Cocoa — 1 cup	12.54	84.30	21.66
Sponge cake	10.26	40.48	102.60
<i>Dinner</i>			
Beef, round	49.02	74.3	—
Potatoes	9.12	2.52	83.22
Cabbage	3.42	22.77	6.84
Carrots	4.06	3.20	33.60
Bread	20.52	7.59	121.98
Butter	16.96	78.43	2.3
Stewed prunes	3.42	1.01	96.90
	419.08	783.47	1234.44
Total — 2436.99 Calories.			

The food eaten on Jan. 17, 1915, was sufficient in quantity for the average girl, but hardly enough for a boy. It did not contain the proper proportion of protein for either a girl or a boy.

By experiment on athletes, soldiers, teachers, and others it has been found that one seventh of the Calories should be got from proteins, and six sevenths from fats and carbohydrates.

An examination of your food for two days will show you whether you are eating wisely, and if not, in what respect your meals are deficient. You can see whether you are getting 2400 Calories per day, and whether you are eating the proper proportion of proteins to fats and carbohydrates. The Table of Food Values on page 80 states the number of Calories of proteins, fats, and carbohydrates given to the body by a single serving of the various foods, and you can calculate the Calories obtained at a meal. If you eat 1 fresh apple, it yields you 2.3 Calories from protein, 5.1 Calories from fats, and 88.9 Calories from carbohydrates; one piece of roast beef, 65.0 Calories from protein, 10.1 Calories from fats, and none from carbohydrates; 1 serving of potato, 9.1 Calories from protein, 2.5 Calories from fats, and 83.2 Calories from carbohydrates. If you are getting less than the standard number of Calories per day and if proteins are yielding less than one seventh of that amount, your meals must be more carefully planned or you must eat more. Girls and women are apt to eat too little protein and boys and men too much.

We need some bulky foods.—Not all of the food that we eat is digested and used by the body for heat and energy; certain parts, such as skin, gristle, tough cell walls, are indigestible, and are rejected and pass from the body by means of the bowels, as waste matter. The digestible part of the food, that is, the part that can be transformed into tissue, and used for heat and energy, is made ready for use in the alimentary canal, which consists of mouth, throat, esophagus, stomach, small intestine, and large intestine. The alimentary canal is about 25 feet long, and food moves slowly through it, particularly through the long coiled small intestine. If the food is bulky, its large mass stimulates motion of the stomach and intestines, and hastens the movement through the alimentary canal. Because the stomach and intestines work best when they contain enough

coarse indigestible matter to stimulate them to activity, the daily diet should contain foods which have bulk as well as foods which have high food values. Green vegetables, like lettuce and spinach, and fruits, like apples, figs, and raisins, are bulky; that is, they contain a great deal of coarse, indigestible waste matter for a small amount of usable food, and they hasten the process of digestion by rapid movement through the alimentary canal. Since the waste materials in green vegetables and fruits pass off through the bowels, they keep the bowels open and prevent constipation. Some of the best foods to keep the bowels in good condition are corn, spinach, beets, figs, apples, peaches, rhubarb, and brown bread; some of the foods which cause constipation are meat, eggs, peas, beans, potatoes, and white bread.

Mistakes in buying. — The body demands a daily ration of the three classes of foodstuffs, but it is for us to determine



FIG. 38. — Diagram showing the difference in the cost of three foods which give about the same amount of nutrition each.

from what meats, vegetables, fruits, cereals, etc., this supply shall be obtained (Fig. 38).

Generally speaking, meats are the most expensive foods we can purchase, and should be bought seldom and in small quantities. Their place can be taken by beans, peas, potatoes,

TABLE SHOWING FOOD VALUES FOR TEN CENTS										
TEN CENTS WORTH OF	PURCHASE PRICE	OUNCES OF PROTEID				HEAT UNITS OF FUEL VALUE				
		1 Oz.	2 Oz.	3 Oz.	4 Oz.	1000	2000	3000	4000	
Beef, round	.20 per lb.	████████				████████				
Beef, sirloin	.35 " "	██████				██████				
Beef, shoulder	.20 " "	████████				████████				
Mutton, leg	.20 " "	██████				██████				
Pork, loin	.22 " "	████████				████████				
Pork, salt, fat	.22 " "	██				██████████				
Ham, smoked	.21 " "	██████				██████				
Codfish dressed	.18 " "	██████				██				
Oysters	.35 " qt.	████				██				
Milk	.08 " "	████████				████████				
Butter	.42 " lb.					██████████				
Cheese, cream	.32 " "	██████				██████				
Eggs	.48 " dz.	██				██				
Wheat bread	.05 " lb.	████████				██████████				
Corn meal	.04 " "	██████████				██████████████				
Oat meal	.04 " "	██████████████				██████████████████				
Beans, dried	.09 " "	██████████				██████████				
Rice	.10 " "	████				██████████				
Potatoes	1.20 " bu.	██████				██████████				
Sugar	.05 " lb.					██████████				

FIG. 39. — Table of food values.

etc., at less than a quarter of the cost. The average American family eats meat three times a day, while the average family of the older countries rarely eats meat more than once a day. A cheap cut of meat usually contains as much nourishment as a high-priced cut, and can be made tender and appetizing by

proper cooking. In most communities, the expensive cuts of meat are veal cutlets, prime ribs of beef, porterhouse and sirloin steaks, and leg of lamb. The cheaper meat products are numerous and varied, and include brisket for boiling and pot roast, round muscle of beef for steaks, Hamburg steak, rack and breast of lamb, knuckle of veal, shoulder of lamb, and neck of lamb.

Oatmeal and cornmeal are rich in protein, and are cheap and easily cooked. They make good meat substitutes. Oysters yield very little in actual food value and are expensive. Table expenses can be reduced by buying food in season; for example, tomatoes are cheap in summer but expensive in winter. They should, therefore, be replaced in winter by cold-weather vegetables, such as turnips or carrots.

The table below shows the loss resulting from unwise buying :

PURCHASER NO. 1		PURCHASER NO. 2	
Canned peas	\$.40	Dried beans	\$.16
Potatoes . . . . .	.75	Potatoes . . . . .	.75
Butter	1.75	Butter and Crisco	1.00
Eggs	1.28	Eggs . . . . .	.80
Milk	1.40	Milk	1.40
Roasts	5.00	Stews and Hamburg steaks .	2.05
Oysters	1.00	Oatmeal . . . . .	.10
Cereals, prepared . . . . .	.25	Bread, homemade . . . . .	.75
Bread, baker's	1.20	Bread pudding . . . . .	.25
Pies, baker's . . . . .	.50	Bananas . . . . .	.25
Canned peaches . . . . .	.40	Apricots and prunes . . . . .	.25
Cream puffs . . . . .	.20	Canned corn . . . . .	.15
Lettuce and celery . . . . .	.50	Carrots . . . . .	.15
Fresh tomatoes . . . . .	.36	Miscellaneous	2.00
Miscellaneous	2.00		\$10.06
	\$16.99		

In less than a week, Purchaser No. 1 spent for four people almost \$ 7 more than Purchaser No. 2 spent on a family of the same size. The families were about equally well nourished.

Varied diet. — The human body is a much more varied and complex machine than any ever devised by man; personal peculiarities, as well as fuel values, influence very largely the diet of an individual. Strawberries are excluded from some diets because of a rash which they cause on the skin, pork is excluded from other diets for a like reason; cauliflower is absolutely indigestible to some and is readily digested by others. From practically every diet some foods must be excluded, no matter what the fuel value of the substance may be. But the average healthy person can eat anything that is fresh and well prepared. If a food repeatedly causes indigestion, it is wise to replace it by food which is easily digested.

TABLE OF FOOD VALUES SHOWING AMOUNT OF PROTEIN, FAT, AND CARBOHYDRATE IN ONE SERVING OF VARIOUS FOODS

ONE SERVING OF FOOD	CALORIES FROM			ONE SERVING OF FOOD	CALORIES FROM		
	Pro- tein	Fat	Carbo- hydrate		Pro- tein	Fat	Carbo- hydrate
Almond	5.7	35.4	4.5	Blanc mange	11.4	75.9	55.8
Apples, baked	2.3	5.0	88.9	Brazil nuts	10.2	83.5	4.5
fresh	2.2	5.0	88.9	Bread, corn	18.2	22.8	106.0
pie	33.0	78.4	164.1	graham	20.5	10.1	118.6
sauce	1.1	7.6	148.2	homemade	20.5	7.6	122.0
Asparagus	20.5	10.1	72.9	Buns	11.4	15.2	68.4
Bacon	11.4	167.0	—	Butter	16.9	78.4	2.3
Banana	5.7	5.0	87.8	Buttermilk	20.5	9.6	33.2
Beans, baked	35.3	45.5	114.0	Cabbage, boiled	3.4	22.8	6.8
soup	43.3	17.7	114.0	Cake, chocolate	16.9	50.6	182.4
Beef, chuck	65.0	10.1	—	lady	4.6	7.6	34.9
corned	23.9	131.5	—	jelly	17.1	30.3	249.6
dried	29.6	17.7	—	sponge	10.2	40.5	102.6
liver	46.7	22.8	3.4	Caramels	5.7	—	92.3
round	49.0	74.3	—	Carrots	4.0	3.2	33.6
Beets	5.7	.5	17.1	Celery, fresh	1.1	.8	4.5
Biscuit				soup	125.4	86.0	19.4
homemade	19.4	12.7	125.4	Cheese, cottage	35.3	22.8	10.2
soda	21.6	68.3	114.0	ordinary	29.6	86.0	2.3

TABLE OF FOOD VALUES SHOWING AMOUNT OF PROTEIN, FAT, AND CARBOHYDRATE IN ONE SERVING OF VARIOUS FOODS (*Continued*)

ONE SERVING OF FOOD	CALORIES FROM			ONE SERVING OF FOOD	CALORIES FROM		
	Pro- tein	Fat	Carbo- hydrate		Pro- tein	Fat	Carbo- hydrate
Chicken	85.5	22.8	—	Grapes	5.7	13.2	80.9
Chocolate, sweet	5.8	55.3	99.8	Gravy	3.4	63.7	8.0
Chops, lamb	49.0	149.3	—	Ham	55.8	131.8	—
pork	53.6	240.3	—	Hickory nuts	9.1	86.0	6.8
Cocoa, cup	12.5	84.3	21.6	Ice cream	21.2	63.2	63.8
Cod fish	36.5	50.6	—	Lamb, chops	49.0	149.2	—
Cookies	12.5	37.9	125.4	roast	76.4	111.3	—
Corn, canned	9.1	7.6	59.3	Lemon pie	16.9	10.1	169.6
flakes	8.0	.7	67.2	Liver	67.8	43.0	—
soup	16.9	84.3	45.6	Macaroni	41.0	5.0	228.0
Crackers, graham	11.4	22.8	84.3	Milk	21.6	60.7	34.2
soda	11.4	22.8	83.2	Mutton chops	49.0	149.2	—
Cranberry sauce	1.1	5.0	34.2	Oatmeal	38.0	36.0	152.0
Cream				Orange	7.7	1.9	18.0
2 tablespoons	2.3	86.0	4.5	Oysters, 4 raw	23.1	11.3	12.7
whipped	14.8	22.8	5.7	soup	23.2	37.2	23.7
Cucumber pickles	.7	1.0	3.4	Parsnips	3.4	32.9	33.1
Currant jelly	1.1	—	87.8	Peanuts	14.8	48.0	13.7
Custard pudding	18.2	—	34.9	Peas	14.8	25.3	22.8
Dates	4.5	12.6	67.2	Pickles	.7	1.0	3.4
Doughnuts	13.7	—	106.0	Pork chops	53.6	240.3	—
Eggs, 2 boiled	72.9	126.5	—	Potatoes	9.1	2.5	83.2
omelet	54.7	222.6	3.4	Potato salad	10.2	55.6	33.1
on toast	34.2	43.0	33.1	soup	12.5	7.6	42.2
poached	20.5	37.9	—	Prunes	3.4	1.0	96.9
scrambled	27.3	43.0	3.4	Pumpkin pie	17.1	37.9	114.0
uncooked	71.8	144.2	—	Rice pudding	13.7	70.8	62.7
Egg mayonnaise	29.6	63.2	2.3	Shredded wheat	23.9	7.6	63.8
Egg plant	10.2	37.9	54.7	Sugar	—	—	18.5
Farina	50.1	13.2	342.0	Tapioca pudding	12.5	25.3	104.9
Figs	10.2	2.5	171.0	Toast	6.8	—	34.2
Fish, trout	12.0	15.0	—	Tomato soup	14.8	30.3	37.6
Fruit salad	4.5	5.0	59.3	Turnips	2.3	27.8	12.3
Gingerbread	13.7	45.5	169.6	Walnuts	9.1	80.9	9.1

CHAPTER VI

COOKING AND ITS EFFECT ON FOOD

The changes produced in food by heat. — Some foods, like nuts, fruit, and milk, are eaten without being cooked; others, like meats, fish, and many vegetables, are eaten only after careful cooking. Cooking changes the nature of foods and usually makes them more easily digested or more completely digestible and more appetizing. We digest a cooked potato more easily than a raw potato; we digest a larger proportion of cooked meat than of uncooked meat; we eat bread with more relish than we would eat an uncooked flour and water mixture; we enjoy a slice of savory, juicy roast more than a slice of raw meat. The changes brought about in foods by cooking are due to heat. All foods can be grouped into two great classes, animal foods and vegetable foods; but animal and vegetable foods differ greatly in composition and in structure, and hence are differently affected by heat. In order to cook the various foodstuffs to advantage we need to know the effect of heat on the different classes of foods.

The effect of heat on protein. — The white of egg is albumen, a form of protein matter. When the colorless, slimy white of egg is heated to 134° F., it changes to a semitransparent, jelly-like mass; when it is heated to 160° F., it coagulates or becomes opaque and more or less solid. Experiments have shown that albumen cooked at 160° F. is more easily digested than albumen cooked at higher temperatures. The effect of different temperatures on albumen can be seen by a simple experiment done at home. Drop an egg into boiling

water and let it remain there for three minutes. Drop another egg into boiling water which has just been removed from the fire, and let it remain in the slowly cooling water for six minutes. Since boiling water rapidly loses heat when removed from the fire, the second egg is cooked at a much lower temperature than the first egg. When the two eggs are opened and examined, it is seen that the boiled egg has a coagulated albumen which is hard and tough, and that the egg cooked more slowly at a lower temperature has a coagulated albumen which is tender and delicate. Eggs, therefore, which are cooked for six minutes in hot water are more digestible than eggs cooked for three minutes in boiling water.

Moderate heat makes albumen tender, delicate, and digestible; strong heat makes it tough, dry, hard, and indigestible. Too hot a fire is the cause of most bad custards, because when egg and milk are put into a hot oven coagulation occurs and the custard curdles and shrivels; an experienced cook uses a cool oven or else she puts her custard cups in a large pan of water. The custard cannot become hotter than the water which surrounds it, and since the water is constantly evaporating, it does not become very hot and the temperature of the custard remains below the danger point.

Milk which is cooked by boiling has a thick scum of indigestible protein matter on its surface; milk which is cooked at moderate temperature has no such indigestible scum.

Coagulation of albumen is put to good service by the housewife in her use of eggshells for clearing coffee. When the eggshells are dropped into coffee, the albumen which clings to them slowly coagulates and rises to the surface of the coffee. As it rises through the coffee, it carries with it the scattered grounds and clears the coffee.

Composition of meat. — Lean meat consists mainly of muscular tissue, connective tissue, and meat juices. Muscular

tissue is made up of bundles of muscular fibers, which appear single to the unaided eye, but which are in reality composed of hundreds of thin, delicate muscle tubes held together by connective tissue. The delicate muscle tubes are composed of a substance known as fibrin, while the connective tissue which binds them together is composed of a totally different substance known as collagen or gelatin.

Meat juices are rich in albumin and in extractives or substances which give flavor to the meat. The substances which give flavor to meat are called extractives because they are easily removed or extracted from it. For instance, if meat is soaked in cold water, the flavoring substances pass into the water and the meat becomes tasteless.

The effect of heat on the constituents of meat.—One object of cooking is to soften and to loosen up the connective tissue and to make it easier for the digestive juices to act upon both connective tissue and muscle fibers. Gelatin, the main constituent of connective tissue, softens and swells under the influence of heat, and if the heat is continued long enough, it slowly dissolves. Meat should not be cooked until the gelatin of the connective tissue dissolves and the muscle fibers fall to pieces, but it should be cooked until the raw gelatin has been softened and converted into a substance readily soluble in the digestive juices of the body.

Gelatin is frequently removed from meat and used as a basis of desserts. It is obtained by cooking meat in hot water until the gelatin in it softens and dissolves in the water. The water is then evaporated away and the soft dry mass which is left is packed in boxes and sold as prepared gelatin.

Albumin which is present in the meat juices is affected by heat in exactly the same way that albumen in eggs is affected. Slow cooking with moderate heat softens and loosens the connective tissue, makes the muscle tubes tender and less compact,

and coagulates the albumin into a soft digestible mass. Rapid cooking at high temperature dissolves the connective tissue, but hardens and toughens the muscle tubes and the albumin, and dries out the extractives.

You may be familiar with the stringy, tasteless meat which has been cooked at too high a temperature. The intelligent application of a few facts regarding the effects of heat upon food constituents will make more savory and healthful dishes for the table.

Roasts and steaks. — All of us know the difference between a tender, juicy, tasty roast and a tough, dry, tasteless one. The flavor of meat depends mainly upon extractives found in the meat juices, and if cooked meat is to be tasty and savory it must be cooked in such a way that its juices and extractives are not lost.

Meat that is to be roasted should be placed for a few minutes in a hot oven, because strong heat coagulates the protein on the surface and forms a brown hard crust over the meat which prevents the escape of juices and extractives. The oven should then be cooled and the meat cooked more slowly at a lower temperature, because if the high temperature is continued, the surface crust thickens and the whole roast becomes leathery, hard, and tough. The crust, which prevents the escape of juices and extractives, also hinders the passage of heat to the inside of the meat, and hence if the roast is large and thick, its cooking must be hastened by basting; that is, by dipping up the fatty liquid which drips into the pan and pouring it over the outside of the meat. Large roasts that are not basted cook so slowly that the outside crust becomes hard and burned before the inside flesh is sufficiently cooked.

Steaks that are to be broiled should also be put over a fire hot enough to sear the outside quickly and prevent the escape of meat juices. Steaks that are to be fried need a very hot

fire, because it is desirable to prevent not only the escape of juices from the meat, but also the entrance of fat into it.

Only young and tender meats should be roasted, broiled, or fried; in young animals such as spring chicken and spring lamb, the tissues are soft and tender and do not need long heat for softening the fibrin. In older animals the tissues are thicker and harder and must be greatly loosened and softened before they are ready for the digestive juices, and they are best prepared by the slower method of stewing and boiling.

Boiling and stewing. — Meat that is to be cooked by boiling should be plunged into boiling water for a few minutes, or until the surface protein has coagulated into a crust through which juices and extractives cannot escape. The pot should then be pushed to a cooler part of the stove where it can be left for hours, the albumin slowly coagulating, the gelatin gradually softening, the fibers slowly loosening, and all being made ready for the body. Meat that is to be boiled should never be put into cold water and heated gradually, because cold or lukewarm water draws out extractives, juices, and soluble protein, and leaves the meat tasteless and poor in nourishment.

In a stew the meat must be tender and juicy and the broth must be rich, for both are to be eaten. In order to get some of the nourishing and flavoring matter in the broth the meat is chopped and soaked in cold water and then heated gradually. With prolonged moderate heat of about 180° F. the connective tissue softens, the fibers loosen up, and the protein coagulates into a soft tender mass. In stewing, as in boiling, long, slow cooking at moderate temperature is better than rapid cooking at the boiling point.

Soups. — In soup we want a rich, well-flavored broth. Since cold and lukewarm water draws out extractives and soluble proteins, meat for soup should be chopped up and then placed in cold water and slowly heated. The temperature should not

exceed 180° F., because if it does the protein in the soup coagulates and rises to the surface as disagreeable and indigestible scum. Soup is improved if it is cooked until the connective tissue partly dissolves, because then the gelatin gets into the soup and thickens and enriches it. After the soup is finished the meat is tasteless; but although it is tasteless, it contains considerable nourishment and should be strained off and used for hash. When finely chopped and flavored with onion, carrot, red peppers, tomato, and other vegetables or condiments it makes an appetizing and nourishing dish.

The double boiler. — Slow cooking with moderate heat is the best way to cook most meat and milk, and hence it is desirable to have simple devices by which the proper temperature can be secured. The double boiler is the solution of the problem (Fig. 40). The vessel containing the soup or boiling meat or the milk is placed in a large vessel containing water.

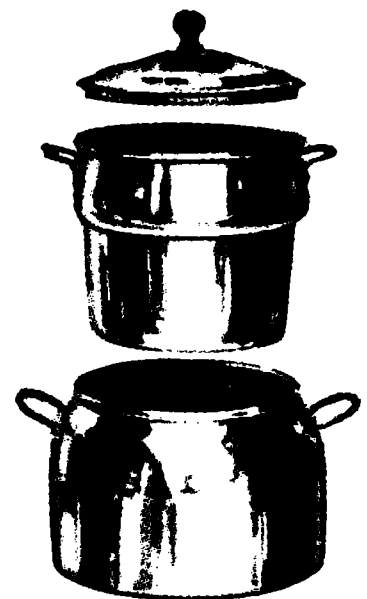


FIG. 40. — Double boiler.

The water in the outer vessel gives heat to the inner vessel, which never gets as hot as the boiling point of water. This removes all danger of overheating the food. The double boiler is invaluable in a household, not only for cooking of meats and heating of milk, but also for making of cocoa and for the slow, thorough cooking of many foods.

Effect of heat on starch. — Most plant foods are eaten for the sake of the starch which they contain. But the starch is in the form of small grains with a hard outer shell which digestive juices cannot penetrate; moreover, the hard starch grains are massed together in cells whose walls are of cellulose, or woody matter. Cooking in hot water softens the woody cell walls and the starch shells, and causes the starch to absorb moisture, to swell, and to burst open their shells. Uncooked

vegetables and cereals are indigestible because the digestive juices cannot penetrate the cell wall and grain shells and reach the starch within. Well-cooked plant foods are digestible and nourishing because the digestive juices are able to reach the starch, to act upon it, and to make it ready for bodily use.

Overcooking. — Since cellulose, the woody tissue of plant cells, is tough, and since the shell of starch grains is hard, high temperatures are needed to cook plant foods. But it is possible to overcook plant foods; all of us, for example, are familiar with soggy, overdone, dark potatoes. When starch remains too long in hot water it absorbs sufficient moisture to change it into a soggy, gummy mass which is both unpalatable and indigestible. As soon as potatoes are done; that is, as soon as the starch grains are soft, swollen, and fluffy, the water should be poured off and the potatoes should be kept warm by dry heat. What is true of potatoes is true of other vegetables; carrots which stand too long in water lose their crispness and become soggy and unpalatable.

Cereals contain so little water and so much starch that they must be cooked in a great deal of water and need prolonged heat to swell the abundant starch grains; hence it is almost impossible to overcook them. The ideal way to cook cereals is in a double boiler.

Loss of food material. — Vegetables, like meats, contain extractives, mineral matter, and other food substances which are extracted by water. For this reason green peas, young carrots, new beans, and other tender vegetables should be cooked in a small amount of water, and when they are nearly done, the lid should be removed from the vessel and most of the water should be allowed to evaporate. The water which remains will contain concentrated extractives and nutritive material and should be served with the vegetables. Most old vegetables have strong flavors and hence should be cooked in

a large quantity of water, which can be drained off later and used as a basis of soup. In vegetables like onions, the extracts are too strong to be desirable and the water should be poured off several times and replaced by fresh water. In doing this we lose something in nourishment, but what we gain in milder flavor more than balances the loss in nutritive material.

Starch and sugar. — Green apples and all unripe fruits contain raw starch, and when eaten disturb the system rather than help it. Ripe apples, on the other hand, contain starch which has been transformed by nature into sugar, a substance easily digested. Plant foods, like ripe fruits, in which the starch has been converted into sugar, are digestible without cooking. In vegetables, whether ripe or unripe, and in cereals the transformation of starch into sugar has not taken place, hence vegetables and cereals should be cooked.

Cooking kills injurious animals and germs in meat. — Small animals and germs injurious to the body are sometimes present in meats; pork, for example, may contain small worms called trichinæ; both pork and beef may contain young tapeworms, and all meats may contain disease germs. If the meat which contains trichinæ, tapeworms, and other parasites is not cooked, the living animals and germs get into the body and cause trouble. Trichinæ make their way to the intestines, where they reproduce rapidly; the young trichinæ bore through the walls of the intestines, enter the blood, and are carried to muscle cells which they bore into and kill. Young tapeworms fasten themselves to the walls of the intestines, absorb food which is meant for human cell growth and repair, and rapidly grow into long tapelike worms. Cooking kills trichinæ, tapeworms, and disease germs, and makes meat containing them safe and harmless.

Some states have rigid inspection of all farm animals intended for food, and cows, pigs, and sheep which are

diseased are condemned and their sale for food is forbidden. But many diseased animals escape detection, and the safest way to avoid danger is to cook all meats thoroughly. Disease germs and dangerous animal parasites such as trichinæ and tapeworms do not grow readily in fruits and vegetables, but disease germs may get *on* fruits and vegetables during handling and transportation. Uncooked fruits and vegetables such as peaches, lettuce, etc., should therefore be carefully and thoroughly washed in clean water before they are eaten.

CHAPTER VII

THE DIGESTION OF FOOD

THE food we eat is destined to become blood, bone, muscle, nerve, etc. But before food can become part and parcel of our bodies, it must be digested; that is, it must be so softened, dissolved, and chemically changed that it can pass through the walls of the alimentary canal and reach the vessels which carry it to the different parts of the body. The alimentary canal (Fig. 41) in which food is digested or made ready for absorption into the blood consists principally of mouth, stomach, intestines, and of the glands which pour secretions into these organs. The salivary glands which open into the mouth, the gastric glands in the stomach, the intestinal glands in the intestines, and the liver and pancreas glands which open into the intestine, secrete chemical compounds called ferments. These ferments act upon carbohydrates, proteins, and fats and change them into substances which can pass through cell walls and be absorbed by the blood. If the digestive glands fail to supply ferments, the food we eat lies undigested in the alimentary canal and is worthless for cell growth and repair. In the normal healthy body the various glands send abundant secretions into the alimentary canal, and the food is soon changed into sub-

FIG. 41.—The alimentary canal.

stances which pass through the walls of the stomach and the intestines.

Digestion is a mechanical as well as a chemical process. Food must be crushed and ground into bits by the teeth in order to be swallowed and sent to the stomach, and it must be kneaded by the muscular walls of the stomach and pushed forward into the intestine. Food must also be crushed and ground up by the teeth in order that the saliva may be thoroughly mixed with it, it must be moved up and down and back and forth by the stomach muscles in order that the gastric juice may come in contact with its whole mass, and finally it must be squeezed and turned by the intestinal muscles and brought into contact with the intestinal fluids. Whether our digestion is good or bad depends largely upon the manner in which we eat. When we eat slowly and chew our food thoroughly, it passes into the stomach well mixed with saliva and so softened and diluted that the gastric juice reaches every particle of it. When we eat rapidly, our food is not thoroughly ground, and it passes into the stomach poorly mixed with saliva and so coarse and unsoftened that it is unfitted to mix readily with the gastric juice.

Digestion begins in the mouth. — Saliva is the watery secretion of the salivary glands. It is important in digestion because it softens and moistens foods and makes them easier to swallow and because it acts chemically upon starchy foods and changes them into sugar which can pass easily through the cell walls and mingle with the blood. The digestive or chemical action of the saliva on starch is due to a ferment, called ptyalin. But although ptyalin changes starch to sugar, it is powerless to bring about chemical changes in protein and fat. The protein and fats which we eat pass into the stomach unaltered chemically.

The action of saliva on starch is the first chemical step in digestion, and it is within our power to increase or to decrease the amount of saliva secreted by the salivary glands. We can

increase the flow of saliva by thorough chewing because chewing stimulates the salivary glands and causes them to secrete more abundantly. We can increase the flow of saliva by serving foods in such a way that their appearance and odor are pleasant. Often the mere sight and odor of food stimulate the flow of saliva so quickly and effectively that the mouth waters. We can increase the salivary secretion by agreeable conversation and good cheer during meals, because these excite the glands to activity, while anger, worry, and distress paralyze the glands and lessen their secretions. Thorough mastication and well-cooked and well-served foods aid salivary secretion and assist digestion.

Ptyalin does not produce an immediate change of starch into sugar; it acts slowly and requires from ten to twenty minutes to transform cooked starch, and from 1 to 1½ hours to transform raw or uncooked starch. Since food remains but a short time in the mouth, the digestion of starch is not completed in the mouth, but is only *begun* there. From the mouth, food passes by the gullet to the stomach where the ptyalin acts until it is stopped by the gastric juice. Saliva is an alkaline liquid, and its ferment ptyalin cannot act in an acid medium; gastric juice is an acid, and as soon as it is well mixed with the food, it interferes with the ptyalin and stops the transformation of starch into sugar. Food should be thoroughly chewed because the ptyalin will then be abundant and will act on the starchy substances before it is stopped by the gastric juice.

Digestion is continued in the stomach. — Gastric juice, like saliva, is largely water, and like saliva it plays an important part in digestion. It contains two ferments, *rennin* and *pepsin*. Proteins cannot pass through cell walls, but rennin and pepsin change them into soluble peptones, substances which can readily diffuse through cell walls and reach the blood. Gastric glands are stimulated by an appetizing appearance, a

pleasing taste, and a savory odor. Gastric glands are also stimulated by the presence of food in the stomach, but some foods, such as soups and broths, stimulate greater activity than other foods, such as cake and bread. A little warm soup at the beginning of dinner is an aid to digestion because it starts an abundant flow of gastric juice and assists the digestion of heavier foods, such as vegetables, meats, and desserts.

Gastric juice is slightly acid and its ferments act only in an acid medium. Until the alkaline saliva sent to the stomach from the mouth has been neutralized by the gastric juice, the gastric ferments do not act. The larger the amount of saliva swallowed the larger is the quantity of gastric juice secreted to neutralize it, and hence the larger is the quantity of gastric ferment present for the later digestion of protein.

Pepsin and rennin, the gastric ferments, change the chemical nature of proteins and transform them into substances usable by the body; but they are powerless to bring about chemical changes in starch and fats and hence digestion is not completed in the stomach.

Muscular movements of the stomach. — The stomach is a muscular bag or swelling of the alimentary canal, and, when moderately full, holds about three pints. Its muscular walls are constantly contracting and enlarging and by their movements they mix every part of the food thoroughly with the gastric juice. This constant agitation of the food with the gastric juice soon reduces some of the food to a thick liquid mass. As soon as sufficient of the liquid has been formed, the muscle at the opening of the intestine relaxes and allows the escape of the liquid into the intestine. The muscle then contracts and closes the opening. In time more liquid food forms within the stomach, the muscle again relaxes and allows food to escape into the intestine.

The stomach works best when it is moderately full. If it

contains too little, the muscles are not stimulated to activity and digestion is slow. If it is too full, the contractions cannot take place, the food is insufficiently mixed with the ferments and remains undigested, giving a feeling of sickness.

Digestion in the small intestine. — Saliva changes starch to sugar, and pepsin and rennin change protein to peptones, but only a small portion of the starch and protein food we eat is digested in the mouth and stomach. This is because food remains in the mouth only a few seconds and lies in the stomach only a few hours, and is acted upon by saliva and gastric juice for too short a time to undergo thorough transformation into new substances. Fats are not changed at all by either pepsin or ptyalin and require for digestion ferments not found in either mouth or stomach. Undigested fats and partially digested starch and proteins pass from the stomach into the small intestine where digestion is continued and completed by means of intestinal ferments. The small intestine is a narrow, much-coiled, muscular tube about twenty feet long, in which three digestive juices are abundant: the bile sent to it from the liver, the pancreatic juice sent to it from the pancreas, and the intestinal juices secreted by glands in its own walls. Each of these juices is essential to intestinal digestion, but the pancreatic juice plays the most important part and carries on the main work of digestion. It changes starch to sugar, converts proteins into peptones, and splits up fats into substances fit for absorption and bodily use. The intestinal juice also contains ferments which assist in the transformation of starch to sugar, protein to peptones, and fats to soluble substances, but it is less important than the pancreatic juice. Bile, unlike intestinal and pancreatic juices, has no direct digestive power, but it is essential to healthy digestion. It stimulates the walls of the intestines to muscular action and assists in the movement of the food; it also acts as a stimulus

to the ferments, and tends to prevent the decay of food during digestion.

The digestion of starch begins in the mouth, the digestion of protein begins in the stomach, but the change of fats into substances which can be used by the body takes place only in the intestine, because fat is chemically unaffected by ptyalin and pepsin. Food remains in the small intestine from five to fifteen hours and during that time all of it which can be used by the body is digested and absorbed through the thin-walled vessels thickly scattered over its surface. But not every particle of food that we eat is digested; cellulose, for example, is chemically unaffected by all the digestive juices and cannot be changed by them into substances usable by the body. Such undigested matter passes from the small intestine into the large intestine, from which it is expelled by the daily discharge of the bowels. If large quantities of food are eaten or the digestive system is out of order, some digestible matter may also escape digestion and pass off with the undigestible matter.

CHAPTER VIII

FOOD SUBSTITUTES AND ADULTERANTS

A substitute for sugar. — The first sweetening used by man was honey, the sweet sirupy liquid made by bees. Later the sweet juice of the sugar cane became known, and replaced honey for most household purposes. To obtain cane sugar the stalk of the cane plant is stripped of leaves and crushed between heavy rollers, and the liquid which oozes from the crushed stalk is boiled into sirups and sugar. At present much sweetening material is obtained from the roots of beets. A delicious sugar is also obtained from the sap of the rock maple tree, but it is not abundant and is expensive. The sweetening obtained from sugar cane, sugar beet, and maple tree is known as sucrose and supplies the genuine sugar used in commerce and housekeeping. A different kind of sugar called grape sugar or glucose is found in ripe fruits, and small granules of it are seen on the outside of dried fruits such as raisins. Glucose is only two fifths as sweet as sucrose, and larger quantities of it must be used in order to obtain the same sweetening effect. There is very little of it in fruits and no attempt has been made to extract it for commercial purposes.

The quantity of sugar needed for cooking and for confections is enormous and because of the high prices of natural sugars, cheaper and more abundant substitutes are used. It is no exaggeration to say that most of the filling used in candies and icings is not natural sucrose but a sugar artificially manufactured from starch and acids. This artificial sugar is made by heating starch in dilute hydrochloric acid. The starch

slowly changes to sugar, and after long-continued heating not a trace of it remains. When the starch has been completely changed to sugar, chalk or soda is thrown into the liquid mass in order to neutralize the surplus acid. The entire mass is then filtered, and the filtrate is boiled down to a thick, straw-colored, transparent substance about three fifths as sweet as cane sugar. The sweetening thus made is usually called corn sirup, because it is made from cornstarch and has the thickness of a sirup; it is also often called glucose, because of its similarity to the sugar found in grapes and other fruits. Practically all of the table sirups sold to-day are corn sirup to which color and flavor have been added, the desired flavor being obtained by mixing some real molasses with the corn sirup. Inferior jams and jellies are usually thickened by artificial glucose, and the filling of cheaper candies is almost universally artificial sugar. The thick sugary mass can be easily worked into fondant and made the basis of candies. Since glucose is less sweet than cane sugar, confectioners work into it a small amount of cane sugar, or else sweeten the corn sugar with a bit of saccharine, a coal tar product three hundred times as sweet as sugar. Because starch and acid are cheap, glucose is inexpensive, and confections made from it can be sold at lower prices than those made from sucrose. So far as is now known, carefully prepared artificial sugar is not harmful, but is easily digested and assimilated. The original outcry against glucose was caused by the carelessness shown in its manufacture, the failure to neutralize the acid used, and the use of undesirable chemicals to bleach it for use in candies. Artificial sugar is a substitute, however, and its presence in food should be shown by a label. Saccharine is harmful and materials sweetened with it are injurious.

Vinegar and its artificial preparation. — Pure or genuine vinegar consists of the fermented juices of fruits and grains,

but much of the vinegar which we purchase is artificially prepared from wood. When fruit juices, such as juices of apples and grapes, are exposed to the air for a long time, they ferment; that is to say, yeast plants from the air make their way into the fruit juices and change the sugar of the fruit into alcohol. The results of yeast fermentation are alcoholic drinks known as cider or wine. When these alcoholic drinks are continuously exposed to the air, further fermentation occurs, bacteria develop in the cider and wine and change the alcohol to acetic acid. As a result of the bacterial fermentation or the change of alcohol to acetic acid, vinegar is formed. Masses of vinegar-producing bacteria collect at the bottom of vinegar bottles and barrels and are known to the housewife as "mother of vinegar."

Acetic acid may be made commercially by pouring dilute alcohol into kegs full of beech wood shavings over which some mother of vinegar has been placed (Fig. 42). As the alcohol flows over the shavings the bacteria act upon it and change it to acetic acid. This is a quick method of making vinegar.

FIG. 42.—Making vinegar.

Much of the acid used for pickling and for salads is not vinegar but dilute acetic acid so colored and flavored as to give the impression of real cider or wine vinegar. Burnt sugar or caramel gives a good coloring to the dilute acid, and a small amount of strong apple juice is sufficient to give taste to a large amount of vinegar. So numerous are the attempts to replace genuine material by cheap, artificial substitutes that Pure Food Laws are essential to safeguard the public.

Butter.—Butter is eaten for the sake of the fat which it contains. Milk fat from which butter is made is more easily digested and assimilated than animal fats such as are found in meats, or vegetable fats such as are found in olive or cottonseed

oils. Milk fat is scattered through the milk in the form of tiny globules, but if the milk is allowed to stand undisturbed these globules rise to the surface and can be skimmed off as cream. When milk or cream is vigorously shaken or stirred, as in churning, these globules strike each other, adhere, and form larger and larger masses of fat or butter. As soon as the fat has collected in a large mass, it is removed from the buttermilk, is washed, worked, salted, and colored.

The flavor of butter depends upon bacteria; butter made from sour cream has a distinct flavor because of substances produced by the bacteria which changed the sweet cream to sour cream. Butter made from sweet cream would lack the agreeable flavor unless it was added in some way. The flavor of sweet cream butter is secured by putting bacteria into the sweet cream before agitating it. The kind of bacteria and their number can be regulated in the creamery, and hence the taste can be varied somewhat to suit the purchasers.

Butter that is carelessly made and handled becomes rancid and unfit for use. It is then remade or renovated and sold as fresh butter. If a test tube containing a piece of butter is placed in hot water, the butter melts and the fat rises and floats as a clear yellow layer on the top; the casein or curd in the butter collects as a whitish mass beneath the fat, and the briny water settles to the bottom of the tube. When butter becomes rancid it is put in large tanks and melted, and strong air currents are blown through it to remove disagreeable odors. The whole mass is then cooled; the clear, odorless fat layer on the top is removed, mixed with fresh milk, and re churned. Such renovated butter or butterine is less desirable than fresh butter, and many states protect the public against it by requiring labels on the package. But labels are often of little value because many people do not know what renovated butter is.

Oleomargarine. — The fat of cream is expensive and it is often replaced by cheaper fats. Melted lard, oil pressed from beef fat, and cottonseed oil, mixed with a little milk and churned, give oleomargarine, a product similar to butter in texture and chemical composition but much cheaper. In order to give the oleomargarine taste and flavor a little butter is worked through it. It should not be sold as butter, but should bear a label stating its true character. All fats are more or less similar and oleomargarine made from good lard, beef suet, and cottonseed oil is entirely wholesome and almost as nutritious as expensive butter. It is certainly preferable to poor rancid butter and is widely used in institutions and hotels for cooking.

Olive oil and cottonseed oil. — For many years the most popular oil for table use has been olive oil, but it is safe to say that little of the oil now purchased under that name is genuine. Most edible vegetable oils resemble olive oil in appearance and can be mixed with it to about 25 per cent without altering its flavor. The oil which is generally used as an adulterant of olive oil is cottonseed oil. It is wholesome and nutritious but is much cheaper than olive oil, and the mixture of olive and cottonseed oils should not be sold for the high price demanded for "pure lucca oil." Olive oil is pressed from olives, the fruit of the olive tree; cottonseed oil is pressed from the seeds of the cotton plant; olive oil has the better flavor, but otherwise there is no reason why cottonseed oil should not be used for salads and all cooking purposes.

Adulteration of jellies and extracts. — Home-made jellies are made by boiling down pure fruit juices with sugar to a thick mass; commercial jellies, however, are frequently made by boiling a small amount of fruit in water and thickening the mixture with starch or glucose. Very often none of the actual fruit specified by the label is present, and the jelly consists of poor apples, or just their skins and cores, boiled down with

water and thickened with starch or glucose. Artificial flavor and color are added to such jellies, and the imitation of the real jelly is often so good that many people do not detect the fraud, and think they are eating the preserved fruits indicated on the labels.

Pure fruit juices when boiled down with sufficient sugar readily jelly or stiffen on cooling, but in cheap jellies a great deal of water is used to a small amount of fruit sirup, and jellying will not take place. A little phosphoric acid added to the liquid mass causes jellying, but it gives to the jelly a sharp almost puckery taste and is very injurious to the health. One should beware of jellies which have a sharp acid taste.

The most popular flavorings used in confections are vanilla, almond, and lemon extracts. Real vanilla extract is obtained by soaking chopped vanilla beans in alcohol, and lemon and orange extracts are obtained by treating orange and lemon peel with strong alcohol. Practically all these extracts can be artificially prepared from chemicals, and many of the so-called pure fruit juices of soda water fountains are chemical compounds which resemble in flavor and fragrance the pure fruit juices. Amyl acetate, for example, smells and tastes like bananas; ethyl butyrate, like pineapple; and amyl valerate, like apple, and these chemical compounds are stealthily used in many places for pure fruit flavors.

Many food adulterants and substitutes are harmful to the body, others are objectionable merely because they appear under a false name and are frauds. Pure Food Laws, if diligently enforced, will do much to protect the public against bodily injury and financial fraud.

There are many kinds of frauds. Cloves, mustard, and cayenne pepper often have starch added to them to increase their weight. Ice cream made from poor cream or from milk is thickened with starch, gelatin, lard, or glucose.

Coloring matter in foods. — Foods are colored either to deceive the purchaser or to please him. Deep red jellies give the impression that good and abundant fruit has been preserved; golden yellow cake, that many eggs have been beaten in; bright green peas, that young fresh seeds have been used; and rich red ice cream, that fresh strawberries have been mixed with the cream. Dealers who do not use good material color their poor material in order to make it attractive enough to sell. Many a cake which contains no eggs is so colored that it looks like a rich home-made product; artificial vanilla may be colored with caramel until it has the shade of the pure extract; mustard may be a mixture of dyed flour and mustard. Uncolored oleomargarine is oleomargarine and deceives no one, but colored oleomargarine may pass for butter. In all of these cases the public is cheated, because it does not get genuine material.

Foods are sometimes dyed in order to please rather than to deceive. Vivid green Hallowe'en candies owe their brilliant color to dye; so do the pink icings and decorations on cakes and candies, and the different colored ices served at parties and receptions. The public knows that pure sugar and cream are white, nevertheless it wants colored candy and colored ice cream. Artificial coloring is due to vegetable dyes or to aniline dyes. Vegetable dyes which come from well-known harmless plants are harmless and can be used without injury to the body. The water drawn from boiled spinach will give a green color to candy and icings, that from beets, a red color, and that from carrots, a delicate yellow. All of these can be easily obtained in the home and used for artificial coloring. Turmeric (orange), indigo (blue), and annatto (yellow) are well-known vegetable dyes formerly used in commerce. But harmless vegetable dyes are not so cheap as coal tar or aniline dyes and do not give so vivid a color. The green from spinach is never as striking as the green from a coal tar dye; the red from

crushed strawberries is never as brilliant as the red from a coal tar dye. The cheapness of coal tar dyes has made them popular with the manufacturer; their brilliancy has made them popular with the purchaser. Unfortunately many coal tar dyes are manufactured in such a way that they contain some arsenic, and since arsenic is poisonous to the system, foods colored with coal tar dyes may be harmful. Practically no vegetable dyes are sold to-day, and all artificial coloring is made with coal tar dyes. For this reason, the public should be educated to give up its preference for "pretty" candies and icings and be satisfied with the natural product.

Pure Food Laws. — Thousands of people think that the statement "Guaranteed under the Food and Drugs Act, June 30, 1906" is a guarantee by the Government of the purity and wholesomeness of the food bearing the label. This is not true. The Government has not examined the material and the manufacturer has printed the label. "Guaranteed under the Pure Food Act" is merely the manufacturer's statement to the Government that *he* does not consider his products adulterated, misbranded, or injurious to health. Food products containing the guarantee should be just as carefully examined by the purchaser as though the guarantee were not there.

CHAPTER IX

BACTERIA AND FOOD. HOW TO KEEP FOOD WHOLESOME

Bacteria spoil food and cause disease.—Milk sours because minute plants called bacteria live, grow, and reproduce in it; meats decay, eggs rot, canned tomatoes sour, and fruits spoil for the same reason. Diseases, such as diphtheria, grippe, pneumonia, typhoid fever, tuberculosis, and diarrhea are caused by bacteria which develop and reproduce in our bodies. But not all bacteria are undesirable and harmful. Certain kinds live in the soil and keep it fertile enough to grow the grains and vegetables on which we depend for food; other kinds grow in milk and cream and give a pleasing flavor to butter and cheese. Bacteria are good or bad according to their work. Those that cause disease and decay of food are often called germs.

Bacteria are hundreds of times smaller than the tiniest fleck of dust, and are so minute that thousands of them could find standing room on the point of a needle, and hundreds of thousands swimming room in a drop of water. Although bacteria are almost unthinkable small, we can see them with the microscope and can study their structure (Fig. 43). They have many different shapes, some are spherical

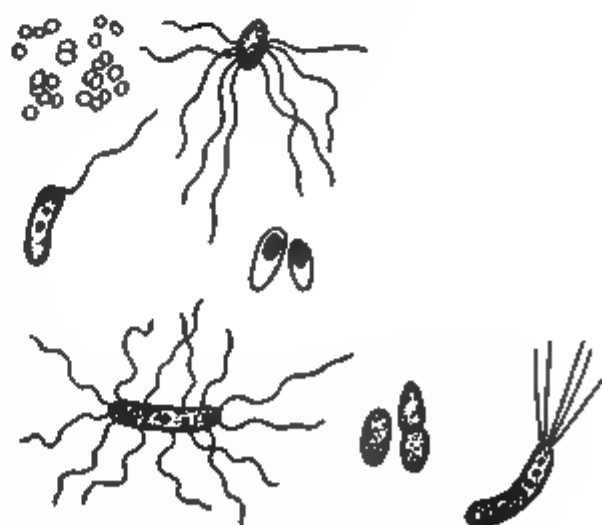


FIG. 43. — Various forms of bacteria, highly magnified.

like shot, some oval like an egg, others cylindrical like a cigar, others spiral like a corkscrew. Some have long hairlike projections, others have short hairlike projections, and some have no projections at all.

Because bacteria are too small to be seen with the unaided eye, they are not easily controlled. The housewife can see the mold which starts on her jelly and can remove it and protect the remainder of the jelly; but she cannot see the bacteria in her canned vegetables and milk, and she does not know that harm is being done by them until it is too late to save the food. Bacteria increase much more rapidly than molds. Jelly does not become badly molded over night, but milk may sour in a few hours.

The abundance of bacteria. — Bacteria are everywhere, in the air, in water, in milk, in dust, in soil, in the mouth, and

on the hands. We can prove that bacteria are in the air by removing the cover from a dish containing especially prepared agar or gelatin and exposing the agar to the air for a few minutes (Fig. 44). If the vessel is put in a warm, dark place, slimy spots appear in a few days. Each spot is a colony of bacteria, and each colony developed from a single bacterium!

FIG. 44. — Colonies of bacteria.

The bacteria from which the various colonies grew drifted to the agar from the air. If the dish contains numerous colonies, the

air contained many bacteria; if the dish contains few colonies, the air contained few bacteria. Bacteria are everywhere in the air, but they are less numerous out-of-doors than indoors, less abundant in light places than in dark places, less abundant in well ventilated rooms than in poorly ventilated rooms.

We can show the presence of bacteria in water, milk, and dust by removing covers from three separate dishes of agar and quickly putting a few drops of water in one, a few drops of milk in another, and a few flecks of dust in a third. If these vessels are set aside in a warm, dark place, colonies of bacteria develop in each. Agar merely touched with the fingers or with a pencil point develops colonies, showing the presence of bacteria on the body and on all the articles we use. Water fresh from the faucet does not produce so many colonies as water which has been standing in the room; fresh milk does not produce so many as sour milk; clean fingers give less than dirty fingers; and dust from open sunshiny places less than old dust from dark damp corners.

Bacteria surround us on all sides, but we can lessen the number in our homes by ventilation and sunshine, in our bodies by personal cleanliness, in our food by protection against air and dust. To protect ourselves and our food against bacteria we must know something of their growth and reproduction.

The growth of bacteria. — When we examine a bacteria colony under the microscope we see that it is composed of an infinite number of individual bacteria. Each bacterium is a simple one-celled organism. It has no green coloring matter, and cannot make its own food, but

takes nourishment whenever
and wherever it can get it.
The bacterium absorbs the



FIG. 45. — Division of a bacterium into two daughter cells.

stolen food materials and increases to a full-grown cell. Then it divides crossways into two halves (Fig. 45), and forms two

small bacteria; each of these grows and divides into two daughter cells. Soon a group or colony forms, the individual cells huddling together in irregular masses or clinging together in chains or other definite forms.

When food is scarce bacteria cease to divide and to form new cells, but many of them develop spores within themselves.

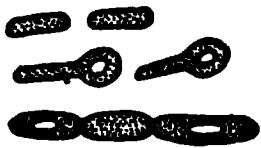


FIG. 46. — Bacteria,
the white spots
are spores.

Spores are hardy and can survive intense cold, strong heat, drought, and lack of food (Fig. 46).

When the bacteria die the spores are set free.

They are very light and are blown far and wide by the wind and start new colonies in widely scattered places. Bacteria do not all form spores; those which do are troublesome to get rid of, those which do not are more easily controlled.

How bacteria cause decay. — Green plants manufacture food for themselves from materials taken from the air and earth. Bacteria cannot make their own food from inorganic matter, but they get nourishment from ready-made foods such as meat, milk, cheese, grains, fruits, vegetables. Bacteria select from the meat or milk some substances as food and reject others, and as a result alter its character. If you burn a match you see that smoke and gases escape from it and that a black crumbling mass remains. A chemical change has taken place in the wood; some of the substances of which it was composed passed into the air, others remained in the charred black mass. Bacteria cause chemical changes in the substances on which they feed. When they get into food they decompose it; that is, they destroy its chemical nature and break it up into other substances. The various new substances which result from the action of bacteria are called decomposition products.

When bacteria get on the surface of meat they decompose it, changing it into substances that are different from fresh meat in

odor, appearance, taste, and character. If the bacteria are not checked in their growth, they quickly spread through the whole mass of meat and make it unfit for use. Some of the decomposition products of bacterial growth have a strong offensive odor, and it is usually possible to detect decay by unnatural odors. Meat, for example, has a slightly offensive odor and an unnatural taste as soon as it is tainted with decay. The decomposition of food particles which have not been thoroughly washed out of cracks and crevices gives a disagreeable odor to garbage cans, kitchen sinks, and dish mops. A bad odor and an unnatural taste in foods is usually a sign that bacteria are in them and that decay has begun.

Ptomaine poisons. — Every living organism, whether plant or animal, throws off waste matter. The wastes of the human body, for example, are perspiration, carbon dioxide, urea, and the discharge from the bowels. Bacteria throw off waste matter or secretions, as they are generally called, and these secretions accumulate in the substances on which the bacteria live. The secretions of some bacteria are harmless to man; those of other bacteria are poisonous and cause disease. Certain bacteria, when growing in food, give rise to decomposition products called ptomaines. Some of these ptomaines are extremely injurious and cause ptomaine poisoning. Tainted meats and fish often cause serious illness because of the ptomaines which they contain. Bacteria develop much more rapidly and throw off more secretions in warm weather than in cold weather, and for this reason there are more cases of illness in summer than in winter. Much sickness is caused in warm weather by ice cream made from milk and cream in which poison-producing bacteria have developed. Poison-producing bacteria develop rapidly in milk in warm weather, and if such milk is fed to babies it brings death to them. One of the most important activities of the "Baby Saving" campaigns

is the distribution of fresh pure milk during the summer months. Fresh food never contains ptomaine secretions.

How to protect our food against decay by bacteria. — It is impossible to have meats, milk, vegetables, and other foods absolutely free from bacteria. The most that we can do is to keep our foods in such a way that the bacteria in them do not develop rapidly and become numerous enough to cause immediate decay. Absolutely fresh foods contain few bacteria, and

if these are kept from increasing, the food remains wholesome for a long time. Bacteria do not grow at the freezing temperature, and therefore foods kept in cold storage retain their freshness almost indefinitely (Fig. 47). Meat is shipped from the west in refrigerator freight cars, and arrives absolutely sound and fresh in the eastern cities.

FIG. 47 — A cold storage room. Notice the frost-covered pipes overhead.

Young chickens are killed

in the spring and kept in cold storage until the following winter, when they bring high prices. The freezing temperature of cold storage vaults stops the growth of bacteria. Temperatures above the freezing point do not stop growth, but merely lessen the rapidity of growth. The temperature of the housewife's refrigerator and the butcher's ice chest is above the freezing point, and does not completely stop the growth of bacteria, which in time become numerous enough to spoil the food. Meat kept in cold storage at the freezing temperature remains good for

a long time, but meat kept in a refrigerator decays after a few days.

Bacteria grow rapidly at summer temperatures and at the temperature of a heated room in winter. In summer, exposed milk sours in a few hours, but remains wholesome all day when kept in a good refrigerator. In summer a dealer keeps the bulk of his meats and fowls in cold storage and brings to his store just enough material to supply the immediate demand. In winter, when the temperature is lower and it is easier to keep the ice chest cold, he pays fewer visits to the cold storage vaults and keeps a larger supply in the store. The more ice there is in a refrigerator, the colder will be the air around the food, and the longer will the food remain in good condition. In warm weather, when ice melts rapidly, and the refrigerator warms up with every opening of the doors, it is better to buy just enough food to last for a short time, and to pay frequent visits to the market for fresh fowl, fish, meat, and vegetables. Fish is particularly sensitive to decay, and a refrigerator must be very cold to prevent the rapid increase of bacteria in fish. Many dealers bury their fish in chopped ice in warm weather.

The average housewife does not buy ice in winter but depends upon the lower temperature of the air to preserve food for a reasonable time. If the weather is cold, turkeys can be purchased weeks before their use and hung in shed or pantry; if the weather is mild, it is not safe to buy them much in advance, because bacteria develop rapidly in them and make them unfit for use.

People who cannot afford ice use several simple devices to keep food from spoiling immediately. Butter, for example, is kept sweet for days in an earthenware jar surrounded by wet cloths. The evaporation of the water from the cloth cools the inside of the vessel and the butter.

Bacteria and moisture. — Bacteria need moisture for growth.

Foods like crackers, cereals, flour, do not decay even in warm weather, because they contain less moisture than is needed for bacterial growth. Meats, fish, fowl, and milk contain abundant moisture, and bacteria develop rapidly in them. Dried fruits such as apples, apricots, figs, prunes, give the dealer little trouble; fresh fruits cause him much loss. He keeps dried beef easily for weeks and months; but fresh meat he must preserve with low temperatures. The Indians knew the value of drying meat; they cut the buffalo, deer, and bear killed on their hunt into long strips and dried them in the sun and wind. The dried meat was their main food during the long idle months that often passed before the next successful hunt. Flour, barley, oatmeal, and crackers protected against moisture do not decay; water-soaked flour, barley, oatmeal, and crackers decay rapidly. The surest way to protect foods against mold and decay is to keep them *cool* and *dry*. A cool dry cellar, pantry, or refrigerator is an essential part of a large household.

But drying is not so popular a preservative as low temperature because dried meat is tough, less digestible, and of a poorer flavor than fresh meat. Dried fruits, such as raisins, prunes, apples, apricots, and dried vegetables, such as lima beans and corn, are not so tasty and palatable as fresh fruits and vegetables, but they are widely used in winter because they are cheap and nourishing.

Salted meats and pickled vegetables. — Bacteria cannot grow and multiply in sugar, salt, or vinegar. Preserves rich in sugar are not apt to spoil; preserves made with little sugar spoil readily. The best way to preserve fruit is to use equal parts of sugar and fruit. Jelly is seldom spoiled by bacteria because it contains so much sugar that they cannot grow in it. Milk may be preserved by sugar; condensed milk is milk from which the water has been removed, and to which a large quantity of sugar has been added. Candied and pre-

served fruits keep indefinitely because of the sugar in them; bonbons and confections become stale, but they do not decay, because they contain too much sugar for the growth of bacteria.

Salt is a universal preservative of foods. Herring, cod, and mackerel caught in the spring are salted and then shipped all over the United States for use as food during the winter. Salt pork and corned beef are safe against decay. Cheese closely wrapped with salty wet cloths, or soaked in salt water, does not spoil, and well salted butter keeps longer than unsalted butter.

Vinegar and most acids stop the growth of bacteria. Pickled beets keep for days in warm weather, while fresh buttered beets spoil rapidly; pickled cucumbers or pickles keep for months and years, but fresh cucumbers become stale in a few days. The Germans pickle a great many vegetables, some of their most common winter dishes being pickled beans and cabbage.

Killing bacteria by heat. — Low temperature does not kill bacteria, it merely keeps them inactive, but high temperature destroys them. Low temperatures hinder growth, moderate temperatures permit slow growth, temperatures of 70° F. to 95° F. cause rapid growth, temperatures above 95° F. check growth, and a high temperature such as that of boiling water not only checks growth but destroys all bacteria. Raw

FIG. 48. — Pasteurizing apparatus, an arrangement by which milk is conveniently heated to destroy disease germs.

or uncooked milk is dangerous for young children because of the bacteria it contains; well heated milk is safely fed to young children because the dangerous bacteria in it have been de-

stroyed by heat (Fig. 48). Uncooked water contains numerous active bacteria, but well boiled water contains no living bacteria.

If you wish to prove that strong heat destroys bacteria, fill two sterilized test tubes half full of milk from the same can. Put one of the test tubes in a bath of boiling water and allow it to remain there for five minutes or longer; then remove it and plug it with cotton. Plug the test tube of unheated milk also, and set both tubes in a warm place side by side. Within a short time, sometimes less than an hour, the unheated milk will sour, but the heated milk will remain in good condition for hours or even a few days. The unheated milk contains bacteria which at the warm temperature multiply rapidly and sour the milk; the heated milk contains few or no living bacteria and hence remains sweet even in a warm temperature. But the heated milk does not remain good permanently; because while the heat was strong enough to kill all of the bacteria, it was not continued long enough to kill the spores and to protect the milk against the bacteria which develop from them when the heating is over. Spores are always harder to kill than bacteria, and unless the heating is strong and prolonged they escape death and grow and multiply when the heated food cools.

It is important to kill the spores as well as the bacteria in fruits and vegetables which are to be canned. The bacteria which grow on corn have spores which are very difficult to kill, and unless corn is boiled an hour or more these spores escape death and later develop colonies of bacteria which spoil the corn. The bacteria which grow in apples, peaches, plums, and most fruits have spores which are killed by a few minutes of vigorous boiling, and hence the canning of these fruits seldom troubles the housewife.

Strong prolonged heat kills the bacteria which are in the

food, but it does not protect the food against bacteria which get in it after the heating has ceased. Food that is to be preserved should be put into sterilized jars (*i.e.* jars washed in scalding water) and the jar should be sealed while hot. If the jars of hot preserves are not promptly sealed, bacteria from the air drift into the rich food substance and develop there and undo the work of the canner. Successful canning consists in cooking fruits and vegetables until all bacteria and spores are killed, and then sealing the cans so that bacteria and spores from outside cannot find entrance.

Killing bacteria by chemicals. — All sorts and kinds of bacteria make their way into foods. Some of them produce decomposition products of disagreeable odors and tastes and cause rapid change in the appearance of the food. Others produce decomposition products without odors and tastes and cause no visible change in the food for a long time. Both types of bacteria may be injurious to health. Those which give warning of their presence by disagreeable odor and taste and by altered appearance in the food are often less dangerous than those which give no such warning.

Manufacturers and dealers have learned that certain chemicals check the growth of the bacteria which cause disagreeable odors and taste. They therefore add these chemicals to foods and keep them in an apparently fresh condition. But the food is not wholesome; it contains dangerous bacteria! For example, milk doctored with formaldehyde remains sweet, because formaldehyde destroys the lactic acid bacteria which cause souring; but milk doctored with formaldehyde, although sweet, is not healthful because it contains the poisonous formaldehyde and a multitude of colon bacteria which are dangerous to health. Milk which does not sour within a few days is probably chemically preserved and is dangerous because of the colon bacteria which it contains.

Carefully canned and properly sealed foods contain no bacteria and remain in good condition indefinitely. Carelessly canned foods contain bacteria and spoil quickly unless protected against the telltale bacteria by preservatives. Unscrupulous dealers add to poorly made catsups and chowchows, chemicals such as alum, salicylic acid, and benzoate of soda. So effective are these chemicals in preventing bacterial growth, that catsup may be left exposed in warm rooms for weeks and months without spoiling. Homemade catsup, however carefully made, spoils quickly if opened and left standing in a warm room, because there are no preservatives in it to prevent the growth of the bacteria which drift from the air.

Stale meat is protected against decay and given a bright fresh color by sulphurous acid. Old and partly decayed meat is sometimes chopped and mixed with sulphites and made into attractive looking but really bad sausage. Boric and benzoic acids are also used to disguise poor meats or to take the place of ice in preserving meats. Most of the chemicals which destroy bacteria in food are injurious to man. Some cause immediate illness by poisoning, others work more slowly, but cause serious illness in time by interfering with digestion and the proper discharge of waste matter from the body.

The safest preservatives are those long known and used by our ancestors, — salt, sugar, vinegar, spices. Salted mackerel, vinegar beets, and pickles are preserved foods, but they are none the less wholesome. Practically all preservatives other than salt, sugar, vinegar, and spices interfere earlier or later with appetite, digestion, and excretion, and should be entirely forbidden by law. Many states allow dangerous preservatives because the manufacturers claim that the amount used is too small to injure the health. But even the smallest amount becomes dangerous when eaten in many different foods. The quantity of preservative in an individual helping of catsup or

jelly or canned corn may be too minute to harm us, but the quantity consumed in catsup *and* jelly *and* canned corn day after day is not minute and can seriously harm the body. Whenever we find boric acid, sulphurous acid, and other similar chemicals, we may be sure that they are used as a substitute for careful canning, as a makeshift for a clean, well cooled ice chest, or as an attempt to sell actually decaying food under the disguise of a false freshness.

Pure Food Laws. — So much harm has been done by food preservatives that most states have made Pure Food Laws. These laws require manufacturers to state on the labels of their boxes or jars what preservatives have been used and in what quantities. But most people never read labels, and many who do, are ignorant of the danger of the chemicals listed on the labels. Some of the most widely sold catsups bear the statement that borax, alum, or sodium benzoate are used in them as preservatives. Their sale continues either because people do not read the labels or because they do not know that these preservatives are undesirable in foods.

CHAPTER X

FUELS

Wood. — Until about 125 years ago, when coal was discovered in Pennsylvania, the only source of fuel was the wood gathered from tree and bush. The log blazing in fireplace and brick stove warmed the dwelling and cooked the food, and served for fuel wherever heat was necessary. To-day wood is largely replaced by coal, although about one hundred million cords of wood are still annually burned in this country for fuel. The discovery of coal was fortunate, since it has preserved for furniture, houses, railroad ties, wharfs, barrels, and other articles, trees which otherwise would have been cut for fuel. The present lumber supply is so limited that anything which conserves wood is a boon to the country.

Wood is an economical fuel in country regions where branches, twigs, and faggots are abundant and where larger logs are obtainable without direct cost, or at the cost of labor only. But in cities and towns where it is bought at high prices wood is an expensive fuel.

Wood burns away quickly, and a wood fire needs constant attention. Charcoal, made by the destructive distillation of wood, burns without flame and gives a good heat. It is popular in hotels, where it is burned in small broilers, the food being served from the broiler as it would be from a chafing dish. Charcoal ignites easily, and small pieces of it are frequently used for starting fires. Coal burns more slowly than wood and a coal fire requires less care. A coal fire can be kept alive all night

with little attention, and in many homes coal fires never go out during the whole winter.

Coal. — Ages ago there grew in what are now the coal regions of the United States, forests which were richer and more luxuriant than the forests of to-day. The leaves, branches, and trunks of these ancient forest trees fell to the ground, sank into the soft moist soil, and gradually became completely covered with wet earth. Slowly the heavy mass of vegetation was buried deeper and deeper in the wet earth and became more and more compressed by the tremendous weight of material accumulating above it. The pressure, the absence of air, and the heat of the earth's interior slowly decomposed the plant mass and brought about changes similar to those brought about in the destructive distillation of wood. In this process, gases were slowly given off, for example, fire damp, the explosive gas so dreaded by men who work in coal mines. After long ages, all that remained of the buried vegetation was a black mass of carbon called coal.

The different kinds of coal. — The change of vegetable matter into coal is a slow process! Countless numbers of years are required to change buried vegetation into coal. When the decomposition has not progressed far, and only a small quantity of gas has been given off, a substance called peat is formed. Peat is a spongy mass of fibrous matter in which remains of leaves or stems are sometimes seen. It is used for fuel in northern Europe, particularly in Germany and Ireland, where hard coal is scarce.

When the decomposition of vegetable matter continues further, more gases are driven off and a rocky mass known as bituminous or soft coal remains.

If the coal regions are not disturbed, more and more gases are driven off, and finally almost pure carbon remains. This carbon is in the form of a hard, brittle rock, and is called anthracite or hard coal.

If decomposition continues still further and absolutely all gases are expelled, graphite—a form of pure carbon—results. Graphite is a shiny black mineral much used in commerce, and known to the housewife as an ingredient of stove polish.

The smoke nuisance.—The dense smoke given forth from puffing locomotives, from factory smokestacks, and from home chimneys is objectionable to all lovers of cleanliness. It settles on curtains and draperies and dulls them; it settles on marble and robs it of its purity; it settles on freshly papered walls and ages them rapidly; in fact, it places its grimy hand on everything and leaves a smudge on whatever it touches. In large manufacturing cities like Pittsburgh, the atmosphere reeks with smoke. The most secluded corners are permeated with smoke-laden air, and house furnishings of somber hue must be used unless the housewife is willing to devote herself unceasingly to the laundry, or is able to replace the delicately colored articles as soon as they are discolored. The smoke nuisance is due to the use of soft or bituminous coal. Until the frightful strike in the anthracite coal mines about fifteen years ago, soft coal was rarely used for fuel. At the time of this strike, hard coal was locked up in the mines and bitter winter knocked at the door. Then soft coal came into use. Since that time it has grown exceedingly popular with manufacturers, and because of its greater cheapness its popularity will doubtless continue. We can readily understand why soft coal is responsible for the smoke nuisance. In soft coal the process of destructive distillation has not gone far. Gases are set free when it is heated in stoves and furnaces, and they burn with a yellow flame, from which smoke issues. The smoke consists of unburned carbon particles which float in the air for a time and finally settle as fine dust does. There is no indication that the use of soft coal will be abandoned, so there is no immediate prospect of freeing our city atmosphere of smoke.

But some manufacturers know that the unburned carbon particles have a high fuel value. These manufacturers use stokers, automatic devices which prevent the escape of unburned carbon particles. The heat from these more than pay for the stokers and the community is spared the smoke (Fig. 49).

FIG 49. — The three chimneys which show no smoke are from furnaces equipped with automatic stokers and large combustion chambers. By these devices it is possible to consume the carbon of the fuel completely, thus preventing the escape of black smoke.

What coal shall we use in the home? — Generally speaking, hard or anthracite coal is the most desirable for household use. It burns with a pale blue flame, without smoke or disagreeable gases. An inexperienced person has greater difficulty in starting a fire from hard coal than from soft coal, because hard coal is more difficult to ignite; but when hard coal is once ignited and the fire is successfully made, less care is necessary than with any other solid fuel. Soft or bituminous coal burns

out more quickly than hard coal, and the supply in the stove has to be renewed frequently.

Coke is a fuel which is growing in use. It is obtained by the destructive distillation of soft coal. It is superior to soft coal because it gives a hotter fire; but it is inferior to hard coal because it burns more quickly and requires more attention.

In choosing coal we must consider the stove, because coal that will burn well in one stove will be a failure in another. Hard coal requires a strong draft underneath it and should not be used in a stove which has a poor draft. Soft coal burns with little draft *under* it, but requires a good draft *over* it to burn the released gases. The stove or range must be studied and tested, and coal which will suit it must be chosen. Then, too, the householder is limited in his choice of fuel by the cost and by the varieties which are available in his town. In some countries briquettes are manufactured and used for fuel. They are made in the shape of bricks and are composed of waste coal dust and other substances. They are cheap and thoroughly satisfactory.

Coal gas, ashes, clinkers. — Fires are usually banked at night in order to keep the fire low until morning. But unless the banking is carefully done a disagreeable odor of gas spreads through the house. In banking a fire a blanket of coal sufficient to last until morning is thrown on the glowing coals and the damper that admits air and the exit damper in the chimney are closed. If the fire is very hot, the burning coals are smothered from above by fresh coal and are smothered from below by the closed draft. The smothered coals undergo partial destructive distillation, and give off poisonous gases. Since the chimney exit is closed, these dangerous gases accumulate in the furnace and from there make their way through loose doors and joints into the house. When this happens, the fire should have immediate attention. Generally it is sufficient to open the chimney

damper for a few minutes; this secures the immediate escape of the harmful gases. Meanwhile the smothered fire has burned so low that it does not produce more coal gas than can escape through loose outlets in the chimney flue. If the fire is hot, the chimney damper must be left wide open for a short time after shutting off the air inlet and smothering the fire with dead coals. If the fire is low, coal gas does not form after "banking," because the temperature is too low to produce the dangerous gas even though the air is shut off.

The bugbear of every wood and coal fire is ashes. They must be removed and the stove must be cleaned if the fire is to burn satisfactorily. Why do we have ashes? Because the vegetation from which coal comes does not consist solely of oxygen, hydrogen, and carbon, but of these substances along with small quantities of other substances which will not burn. These foreign substances are largely minerals, and they are not driven off in the decomposition, neither are they burned up in the fire, but they remain to plague the fire tender. Occasionally some of these foreign substances fuse together and form clinkers, another abomination of the housekeeper.

It is a well-known fact that silver tarnishes more readily in winter than in summer, but few housewives understand why this is true. Coal almost always contains a small amount of sulphur. Some of this sulphur escapes from the heated coal along with the other gases and sulphur unites with silver, forming a black film. In steam and hot-water heating, less sulphur compounds reach the rooms than in hot-air heating, and there is less tarnishing of the household silver.

Oil and gas as fuel. — In summer homes in the country, in vacation camps, and in small towns and villages, oil is largely used for fuel. Those of us who live in cities where coal can always be purchased or where gas is available for stoves in every house, large or small, expensive or cheap, have no idea how

great a boon oil is to persons living in regions cut off from these advantages. In many places oil is used entirely for cooking, because wood is reserved for lumber, or because coal is too expensive to transport, or because gas is not manufactured.

Gas and oil are not economical for house heating, but they are economical for cooking, especially in summer, when the heat for cooking is needed only at intervals. A coal fire burns in the range all day, and even if the fire is kept low except when food is being cooked, a considerable amount of coal is consumed. In oil and gas stoves, fuel is burned only while the food is actually cooking. But in winter, when fuel is used for warming the house as well as for cooking the food, coal is the most economical fuel. The heat given out by ordinary gas and oil stoves is not sufficient to warm a house, but in houses which are poorly heated by coal stoves or furnaces, oil is frequently used to supplement the coal stoves. An oil stove such as is seen in Figure 50 is intended for supplementary house heating. An oil stove of this type may have a different top and be very useful for cooking.

FIG. 50. — Oil stove for heating.

Kerosene or coal oils. — The oils most widely used for cooking are kerosene and gasoline. Both of these are obtained from the thick dark petroleum which occurs as an underground liquid in California, Oklahoma, Texas, Pennsylvania, and some other states.

Crude petroleum, or petroleum just as it comes from the earth, may be used as fuel, and is frequently so used on steamships and locomotives. Usually, however, it is refined or dis-

tilled, and the two main products of the distillation are kerosene and gasoline.

We can easily separate petroleum into some of its constituents in a simple manner in the laboratory. Partly fill a hard glass tube with petroleum and attach it to two U-tubes as in Figure 51. Let the first U-tube *A* rest in a beaker of boiling water, and the second U-tube *B* rest in a beaker of cold water. Heat the petroleum gently and notice the vapors or fumes which rise from it and pass into the U-shaped tubes *A* and *B*. The components of petroleum which have a low boiling point are driven through *A* into *B*, where they are chilled and condensed. When the petroleum is heated more strongly, components which have a higher boiling point are driven off as vapors into *A*.

FIG. 51. — Distillation of petroleum.

Although the temperature of *A* is high, it is still low enough to condense these very hot vapors. Various vapors then condense and collect in *A*. When we pour the contents of *A* and *B* into evaporating dishes and examine them, we are reminded of kerosene, benzine, and gasoline. Since different vapors (that is, all vapors condensing at about the same temperature) condensed in *A*, the distillates which collect there are really a mixture of several substances. The same is true of the distillates in *B*. Benzine vapor, for example, condenses if the temperature is less than 120°C ., kerosene condenses if the temperature is less than 150°C ., and hence in *B* we may find both kerosene and benzine. If we wish to separate the distillates, we can do it by adding more U-tubes

or condensers. The most remote tube would contain gasoline; the next, naphtha; the next, benzine; the next, kerosene; and so on.

When petroleum is heated to a very high temperature, heavier oils vaporize and pass off and condense. From these oils, lubricating oil, vaseline, and paraffin wax are obtained.

Gas as a fuel. — The most convenient fuel is gas. There is no waste to gas and there is no removal of ashes; it is available

at a moment's notice and requires less attention than any other fuel (Fig. 52). For steady use, it is more expensive than coal, and the thrifty housekeeper who does not wish to economize her own labors would not use gas for laundry work where the washing and ironing is an all-day affair. In summer, when comfort as well as economy is to be considered, the gas range



FIG. 52. — Gas range.

is almost indispensable. In practically all of the modern hotels, cooking is done entirely with gas, thereby saving labor and prolonged hot fires.

Most of the gas that is used for cooking and for illumination is made from the distillation of soft coal. In our study of coals we saw that the decomposition of vegetable matter was far from complete in soft coal and that it contains more volatile matter than hard coal. These volatile gases are driven off from soft coal by heating in closed clay-lined retorts from which air is excluded. When the coal is heated to 1200° C. or more, cer-

tain substances in it volatilize and pass through an exit pipe into a trough which contains water, and is called the hydraulic main. Some of the tarry vapors which distill over from the coal condense in the hydraulic main as a thick tarry liquid. Other gases dissolve in the water. Some of the vapors do not condense in the water, but bubble through it into other receptacles. The gases that bubble through the hydraulic main, uncondensed and undissolved, pass onward to a series of coils or tanks, where they are cooled and where as a result of cooling they condense and form valuable commercial products. Some of the gas does not condense at all. This passes from the condensers into "scrubbers" and "purifiers," where it is freed of objectionable material. It is then ready to be used for cooking and lighting. It is stored in huge gas holders from which it is distributed through underground pipes to the buildings where it is burned for light or heat.

Gas for cooking. — If a cold object is held in the bright flame of an ordinary gas jet, it becomes covered with soot, or particles of unburned carbon. Although the flame is surrounded by air, the central portion of it does not receive sufficient oxygen to burn up the numerous carbon particles constantly thrown off by the burning gas, and many carbon particles remain in the flame as glowing, incandescent masses. If enough air were supplied to the flame to burn up the carbon as fast as it is set free, there would be no deposit of soot.

Unburned carbon would be objectionable in cooking stoves, where utensils are constantly in contact with the flame. For this reason cooking stoves are provided with an arrangement by means of which enough air is supplied to the burning gas to insure complete combustion of the carbon particles. An opening is made in the tube through which gas passes to the burner, and as the gas moves past this opening, it carries with it a draft of air. These openings are visible on all gas stoves,

and should be kept clean and free from clogging. So long as the supply of air is sufficient, the flame burns with a dull blue color, but when the supply falls below that needed for complete burning of the carbon, the blue color disappears, and a yellow flame takes its place, and with the yellow flame a deposit of soot on cooking utensils results.

A comparison of the heating power of the different fuels. — Whether our fuel be wood, coal, oil, or gas, it costs money, and it is important for us to know which fuel yields the most heat for the least money. It is not difficult to measure the amount of heat given out by equal quantities of the different fuels. A pound of wood, for instance, is burned in the bomb calorimeter (page 68), and the heat which it yields is calculated from the increase in the temperature of the water which surrounds it. Similarly a pound of coal is burned and its heat value is calculated. To test the heating power of gas, a gas jet is allowed to burn in the calorimeter until a pound of gas is consumed. From the results of such experiments we reach a basis of comparison.

QUANTITIES OF HEAT OBTAINED FROM VARIOUS FUELS FOR \$1

Bituminous coal	@ \$6	a ton gives	1,250,000 large calories
Wood	@ \$8	a cord gives	937,000 large calories
Petroleum	@ \$0.15	a gallon gives	240,000 large calories
Gasoline	@ \$0.20	a gallon gives	175,000 large calories
Gas	@ \$1	1000 cu. ft. gives	170,000 large calories

If prices alone were considered, coal, yielding as it does the greatest heat, would be chosen. But we have to consider not only the actual cost of the fuel, but also the labor necessary to care for a fire, the length of time the fire is needed, and various other conditions. There is no hard and fast rule, and the wise person will vary her household fuel according to circumstances.

CHAPTER XI

CLOTHES AND HOW THEY PROTECT US

CLOTHING protects the body against exposure to heat, rain, and wind, and particularly against exposure to cold. In tropical regions, uncivilized man wears little or no clothing; in cold Arctic regions uncivilized man wears animal skins as a protection against biting cold and bleak winds. Civilized man wears clothes whether he lives in cold northern countries or in balmy southern countries; but he modifies his clothing to suit the various temperatures. In cold climates he wears heavy woolens and furs, in warm climates, thin cottons and linens; in winter he has additional clothes for out-of-door wear; in summer he discards out-of-door clothes and uses the thinnest and lightest materials for all purposes.

Clothing is made of materials obtained from both animals and plants. Wool is the hair of sheep and goats; silk, the cocoon of the silkworm; fur, the hairy skin of wild animals; cotton, the fluffy covering of seeds of the cotton plant; and linen, the slender fine strands running through the stem of the flax plant. The hair of sheep, the fur of beaver, the threads of cotton seeds, the strands of flax stems, are called fibers. Fibers are flexible strands or hairs which can be twisted, plaited, or woven together to form strong, firm threads. Individual fibers are frail and weak, but when numbers of them are closely united, they form strong threads or yarns. The individual threads which show on the ragged edge of cotton material are made by spinning together many single cotton fibers; the yarn which is sold in hanks for knitting is made by twisting and

winding together many single wool fibers. The threads and yarns spun from the different fibers are intertwined by weaving, braiding, or knitting, and form the various materials or fabrics from which clothing is made. There are many different kinds of fibers, such as hemp, jute, pineapple, yucca, but the most important fibers used in clothing are wool, cotton, linen, and silk.

Woolen materials.—Wool fibers (Fig. 53) come from sheep and goats; those fleeced from goats are used to make mohair and alpaca; those from sheep, to make all the other woolen materials familiar to us. Wool is the most valuable fiber in cold civilized countries. Fur is soft and warm and good as an outside covering; but it is rough and disagreeable when worn next to the skin.

1 2 3
FIG. 53. — Wool fibers. 1. Alpaca. 2. Camel. 3. Cashmere.
(Courtesy of Philadelphia Commercial Museum.)

Wool fibers have scales on their surface, which hook into each other, and the various fibers cling well together and are easily woven into

threads. The fibers vary in length from 1 to 10 inches; the longer, coarser fibers are woven into worsted goods; the shorter, finer fibers are woven into threads from which fine woolen fabrics are made.

Wool fibers are soft, light in weight, and elastic, and make soft light-weight, flexible, warm garments. They are usually woven loosely, and hence woolen materials are full of air spaces. Air is a poor conductor of heat, and numerous air spaces in a material prevent the escape of bodily heat. Wool, therefore, is an ideal material for cold climates and nothing can take the

place of wool for clothing. Among the best known woollen fabrics are broadcloth, lady's cloth, serge, etamine, cheviot, covert cloth, cashmere, homespun, flannel, whipcord, and voile.

Wool absorbs a large amount of water without becoming damp to the touch. Men who work in engine rooms and perspire freely wear flannel shirts or blouses to absorb the moisture; cotton and linen blouses would become damp and keep the body wet and clammy. Woolen is unsurpassed for underwear in winter, because if a person is suddenly overheated and then cooled, the wool absorbs the excess moisture and passes it off slowly to the atmosphere without rapid loss of heat to the body. If a person in cotton underwear is overheated, the excess moisture remains on the skin and rapidly conducts heat away, leaving the body chilled. If a person dressed in wool is caught in a shower, he does not suffer, because wool holds the moisture and does not let it pass through to the body; but if dressed in cotton or linen he is quickly wet, because cotton and linen do not hold water but let it pass through them to the body.

Wool should not be carelessly laundered, because it is injured by boiling water and hot irons. If it is to keep its softness, its size, and its elasticity, it must be washed in lukewarm water and ironed with a moderately hot iron.

Cotton and linen materials. — Cotton fibers are flattened, twisted hairs or filaments from one to several inches in length (Fig. 54). The twist of the cotton fiber serves the weaver the same purpose as the scaly surface of the wool fiber; it assists the interlocking of fibers and gives strength to fine yarns; it also gives spring or elasticity to the fibers. Cotton fibers are harder than woollen fibers and are woven more closely; there are fewer and smaller air spaces in cotton materials than in woollen materials, and hence cotton garments permit more heat

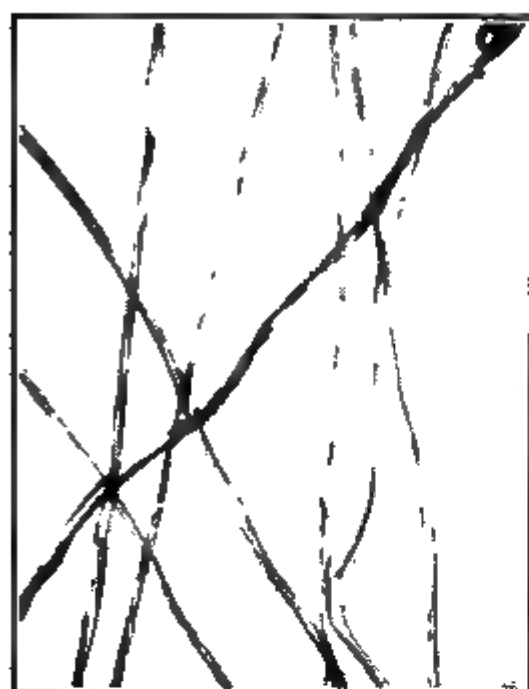


FIG. 54. — Cotton fibers. (Courtesy of Philadelphia Commercial Museum.)

to escape from the body. For this reason cotton materials should be discarded in cold weather and replaced by woolen ones. In summer, when there is no need to protect the body against loss of heat to the atmosphere, cotton is superior to wool. There are innumerable different weaves of cotton materials of widely varied character, such as muslin, lawn, calico, gingham, dimity, mull, crêpe, canton flannel, sateen, and khaki.

Cotton garments are easier to launder than woolen ones because they are not injured by boiling water and by hot irons.

Cotton fibers are readily pulled and torn from seeds (Fig. 55), but flax fibers are not easily removed from flax plants, because they are embedded in the stems and are closely connected with useless woody matter. The stems must be soaked in warm water until they soften and loosen up; the fibers are then separated from the useless materials by beating and combing.

Flax fibers are strong cylindrical strands 12 to 20 inches long, but they are stiff and straight and have little elasticity, and linen materials do not "give" or shape themselves to

FIG. 55. — Cotton bolls.

the body as do cotton and wool materials. The larger fibers are used in the manufacture of fine materials; the shorter ones are used for coarser cheaper materials. When flax fibers are washed, bleached, and woven they make fabrics of snowy whiteness, silky luster, and excellent wearing qualities. But flax plants grow less abundantly than cotton plants, and linen materials are more costly to manufacture than cotton materials, hence linen is more expensive than cotton and less universally used.

Linen is stiffer and harsher than cotton and does not make as soft undergarments; its chief use is for tablecloths and napkins, towels, sheets, pillow cases, bedspreads, and window shades. But many linen fabrics, such as fine cambric and Irish linen, are used for dress fabrics, shirts, collars and cuffs, and for linen suits which are popular in summer. Linen is easy to launder, because like cotton it can be washed in boiling water without injury and can be ironed rapidly with a hot iron. But because of the stiffness of its fibers, linen wrinkles and musses readily and garments made of it need frequent pressings.

Silk. — Silk fibers are the most beautiful of all and make the most attractive but least durable fabrics.

FIG. 56. — A cocoon.

The silkworm builds around itself a silk cocoon in which to live during its transformation into a moth. Before the moth breaks its way out, the cocoons (Fig. 56) are gathered and placed in an oven hot enough to kill the animals but not hot enough to injure the silk. Then the cocoons are soaked in hot water, until the closely wrapped silk fibers are loosened. The delicate fibers are then easily unwound without breaking. Only one fiber is gotten

from a cocoon, but it is from 1000 to 4000 feet long. The silk fibers are thin and fine, and usually those of six or more cocoons are twisted together to make the silk threads used in weaving.

Silk is a good conductor of heat and is not practical as clothing in cold weather; but it makes comfortable dresses in mild temperatures. Among the best known silk fabrics are taffeta, foulard, moire, satin, surah, and crêpe de Chine. The heavy silk fabrics cannot be successfully washed, but there are now many "wash silks" which launder beautifully.

FIG. 57. — *A*, raw silk. *B*, tussah. *C*, artificial silk manufactured from wood fiber. *D*, sample of mixed silk and cotton, from which silk has been removed by hydrochloric acid. (Courtesy of Alma T. Waldie)

Mixed goods. — Fabrics are frequently made of two or more different kinds of fibers; poplin, for example, is a combination of wool and silk; farmer's satin, of cotton and wool. Cotton is the cheapest and most abundant fiber, and it is frequently used as the foundation of mixed fabrics. The

innumerable new and beautiful materials for clothing and house-furnishing are made by new weaves of one kind of fiber or of two or more kinds of fibers used in new proportions and groupings. Fabrics of mixed fibers frequently serve our needs better than those made of but a single kind of fiber; poplin, for example,

is as beautiful as silk and wears far better; farmer's satin has a pleasing luster, and makes a more durable, cheaper lining than either the pure satin or silk which it imitates.

In the early fall, wool is too warm and cotton is too cool and a "half wool and cotton" material such as flannelette is comfortable and serviceable; in many climates "half-wool" underwear is warm enough for all winter.

Frauds and adulterants in fabrics. — Cotton is cheaper than wool or linen, and part-cotton underwear should not be sold at all-wool prices; nor should part-cotton handkerchiefs and tablecloths be sold at all-linen prices. Underwear marked "all-wool" is often 10 to 50 per cent cotton, and sometimes is even 90 per cent cotton; collars advertised as all linen are rarely unmixed with cotton. The large dealers easily detect frauds and adulterants in fabrics, but the retail purchaser is rarely conscious of them and often pays double prices. There are several ways to detect frauds in fabrics: one by microscopic examination and another by chemical means. The different fibers have characteristic shapes and lengths and can be recognized by their appearance under the microscope; all-wool material, for example, when examined under the microscope shows none of the flattened twisted fibers which are characteristic of cotton.

The different fibers differ in composition and react differently to chemicals, and it is possible to test fabrics for purity by chemical means. Cotton, for example, is not affected by caustic soda, whereas wool is dissolved by it. We can tell whether a material is all wool or not by boiling a piece of it for five minutes in a solution of caustic soda. If the material dissolves away completely, it is all wool; if it dissolves only partly, the portion remaining is the cotton. Silk is dissolved by hydrochloric acid, but wool and cotton are not.

A simple test can be made to determine the purity of linen. Cotton retains its original appearance when soaked in olive

oil, but an all-linen sample becomes entirely translucent after soaking for five minutes in it.

Fur. — Animals such as the beaver, seal, rabbit, and cat are protected against cold by a soft silky covering called fur. Between the innumerable fibers which make up the fur is air, and since air is a non-conductor of heat, fur prevents the escape of

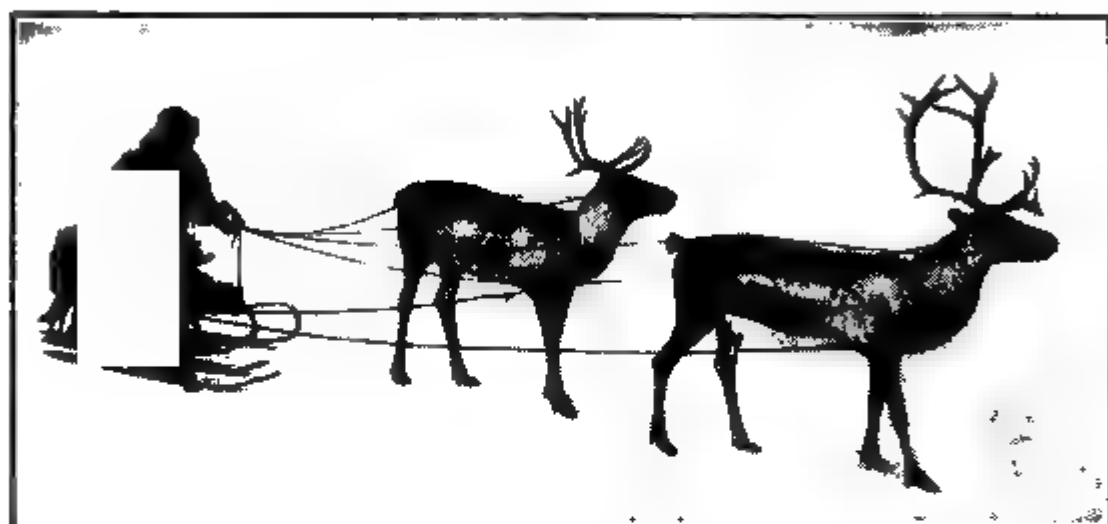


FIG. 58. — Eskimo in fur dress. (Courtesy of Philadelphia Commercial Museum)

bodily heat and keeps the animals warm. For years, man has killed fur-bearing animals and has made their furry skins into garments for his own protection. Eskimos dress entirely in fur (Fig. 58), and thus protect themselves against the extreme cold of ice-bound regions. Inhabitants of less rigid climates do not need so much protection against cold, and dress in less bulky garments of wool and cotton using fur only for outside clothing, such as coats, boas, muffs, and gloves. Among the most prized furs are those of the otter, beaver, sable fox, and ermine, but many other animals, like the skunk, squirrel, and muskrat, furnish valuable furs. The demand for furs is so much greater than the supply that the skin of the domestic cat has been dyed and prepared in such a way that it imitates more costly furs. Under false names, cat furs are sold in large numbers everywhere. Fox skins are so valuable, that attempts have

been made to domesticate foxes and raise them on fox farms. The undertaking is still young, but so far it has been successful. Persian lamb and astrakhan are also highly prized; they are the fur of very young lambs and goats. Fur is the warmest of all known coverings, and its warmth together with its beauty and its softness has made it popular with all people living in cold climates.

Furs are sometimes felted; that is, the fibers torn from the skin are entangled and intertwined to form felt. The glossy silk hats worn by men are made from woven beaver fibers, and ordinary felt hats are made from fibers of more common furs.

Leather. — On animals like the horse and cow, the fur is stiff and coarse, and useless for clothing, but the skin is valuable and furnishes leather for shoes, boots, belts, and hat bands. Skins or hides that are used for leather are soaked in slaked lime until the hairs are loosened and are easily pulled out; after all hairs have been removed, the skins are thoroughly washed and softened by sour bran and dough; they are then soaked for months in an extract of oak or hemlock bark. The extract contains tannin, a substance which slowly unites with the skin and changes it to leather. After the tannin has done its work on the hide, the leather is removed from the tannin bath and is washed, dried, and oiled; it is then ready for use, and is soft, pliable, and durable. Leather that is properly tanned is not injured by water, and shoes made of good leather remain soft and pliable after a wetting. Leather that is poorly tanned dries off hard and stiff and makes shoes that have been wet uncomfortable.

The hides of some animals, the cow for example, are thick, and must be split into three or four layers for most purposes. But split leather is not as durable and soft as leather of equal thickness made from naturally thin skins, like those of the sheep and goat. Kid leather, used for kid gloves, is one of the finest leathers and is the skin of young goats or sheep.

CHAPTER XII

HOUSEHOLD CHEMICALS

Chemistry. — Automobiles, airships, subways, canals such as the Panama Canal, and suspension bridges, show man's progress in mechanical construction. But man's mechanical inventions have been equaled by his chemical researches and discoveries, and by the application he has made of his knowledge of substances.

The plain cotton frock of our grandmothers had its death knell sounded a few years ago, when John Mercer showed that cotton fabrics soaked in caustic soda assumed under certain conditions a silky sheen, and when dyed took on beautiful and varied hues. The demonstration of this simple fact laid the foundation for the manufacture of a variety of attractive dress materials known as mercerized cotton.

Possibly no industry has been more affected by chemical discovery than that of dyeing. Those who have seen the best masterpieces in painting, or reproductions of them, know the softness, the mellowness, the richness of tints employed by the old masters. But if we look for the brilliancy and variety of color seen in our own day, the search will be fruitless, because these were unknown until half a century ago. Up to that time, dyes were few in number and were extracted solely from plants, principally from the indigo and madder plants. But about the year 1856 it was discovered that dyes could be obtained from coal tar in much greater variety and in purer form. This chemical production of dyes has now largely supplanted the original method, and the industry has grown so rapidly that

a single firm produced in one year from coal tar a quantity of indigo dye that would have required a quarter million acres of indigo plant.

The abundance and cheapness of newspapers and coarse wrapping papers are due to the fact that man has learned to substitute wood for rags in the manufacture of paper. Investigation brought out the fact that wood contained the substance which made rags valuable for paper making. Since the supply of rags was far less than the demand, the problem of the extraction from wood of the paper-forming substance was a vital one. After repeated trials, it was found that caustic soda when heated with wood chips destroyed everything in the wood except the desired substance, cellulose; this could be removed, bleached, dried, and pressed into paper. The substitution of wood for rags has made possible the daily issue of many, large newspapers. When we reflect that a paper of wide circulation consumes a ten-acre wood lot per day, we see that all the rags in the world would be inadequate to supply newspapers alone, to say nothing of periodicals, books, tissue paper, and the like.

Chemistry plays a part in every phase of life: in the arts, the industries, the household, and in the body itself, where digestion, excretion, etc., result from the action of the bodily fluids upon food. The chemical substances of most interest to us are those which affect us personally rather than industrially; for example, soap, which cleanses our bodies, our clothing, our household possessions; washing soda, which lightens laundry work; lye, which clears out the drain pipe clogged with grease; benzine, which removes stains from clothing; turpentine, which rids us of paint spots left by careless workmen; and hydrogen peroxide, which disinfects wounds and sores.

In order to understand the actions of these substances we must study the properties of two groups of chemicals known as acids and bases. The first of these may be represented by

vinegar, sulphuric acid, and oxalic acid; and the second, by ammonia, lye, and limewater.

Acids. — We know that vinegar and lemon juice have a sour taste, and it is easy to show that most acids are characterized by a sour taste. If a clean glass rod is dipped into very dilute acid, such as acetic, sulphuric, or nitric acid, and then lightly touched to the tongue, it will taste sour. But the best test of an acid is by sight rather than by taste, because a minute trace of acid is able to discolor a plant substance called litmus. If paper is soaked in a litmus solution until it acquires the characteristic blue hue of the plant substance, and is then dried thoroughly, it can be used to detect acids. If a drop of acid substance is put upon blue litmus paper, it will change the color of the paper to red. The litmus paper test shows that many of our common foods, such as fruit, buttermilk, sour bread, and vinegar, contain acid of some kind. The acid in lemon juice is mostly citric acid; in buttermilk, lactic acid; and in vinegar, acetic acid.

Acids are usually in liquid form. Sometimes, however, they are solid. Oxalic acid, which is so useful in the removal of ink stains, is a solid. But it dissolves readily in water, and an acid solution of oxalic acid is always obtainable. Tartaric acid, an ingredient of some baking powders, is a solid acid.

The damage that can be done by strong acids is well known. If a jar of sulphuric acid is overturned, and some of it falls on the skin, it eats its way into the flesh and leaves an ugly sore; if it falls on carpet or coat, it eats its way into the material and leaves an unsightly hole. The evil results of an accident can be lessened if we know just what to do and do it quickly, but for this we must have a knowledge of bases, the second group of chemicals.

Bases. — Substances belonging to this group usually have a bitter taste and a slimy, soapy feeling. For our present purposes,

the most important characteristic of a base is that it will neutralize an acid and in some measure lessen the damage done by it. If you spill an acid on cloth, apply ammonia quickly and little harm will be done. If you delay, the acid does its work and there is no remedy. If soda (a base) touches black material, it often discolors it and leaves an ugly brown spot; but the application of a little acid, such as vinegar or lemon juice, will often restore the original color and counteract the bad effects of the base. Limewater prescribed by physicians in cases of illness is a well-known base; it neutralizes the excess acids present in a weak system and so quiets and tones the stomach.

The interaction of acids and bases may be observed in another way. If blue litmus paper is put into an acid solution, its color changes to red; if now the red litmus paper is dipped into a base solution, caustic soda, for example, its color is changed back to blue. What the acid does, the base undoes, either wholly or in part. Bases always turn red litmus paper blue.

Most bases are solids, like soda. But they are practically all soluble in water, and when we speak of a base, we mean either the solid base or its solution in water. Calcium hydroxide, for example, is limewater, a solution of lime in water. Bases are sometimes called hydroxides, owing to the fact that they all contain hydrogen and oxygen.

Bases, like acids, are good or bad according to their use. If they come in contact with cloth, they eat or discolor it, unless neutralized by an acid. But this property of bases, harmful in one way, is put to advantage in the home, where grease is removed from drain pipe and sink by the use of lye, a strong base. Dilute ammonia is used in almost every home and is an indispensable servant; diluted sufficiently, it is invaluable in the washing of delicate fabrics and in the removing of stains. In a more concentrated form it is helpful as a restorative in cases of fainting.

Some concentrated bases are so powerful in their action on grease, cloth, and metal that they received the designation caustic, and are ordinarily known as caustic soda, caustic potash (lye), and caustic lime. These more active bases are generally called alkalies in distinction from the less active ones like lime-water.

Neutral substances. — To any acid solution add gradually a small quantity of base, and test the mixture from time to time with blue litmus paper. At first the paper will turn red quickly, but as more and more of the base is added the blue litmus paper will be affected less and less, and finally a point is reached when a fresh strip of blue paper will not be affected at all. Such a result indicates the absence of any acid qualities in the solution. If now a red litmus paper is tested in the same solution, its color also will remain unchanged; such a result indicates the absence of any basic quality. The solution has the characteristic property of neither acid nor base and is said to be neutral. A pinch of soda added to sour milk neutralizes the lactic acid and takes away the sour taste of the milk. Ice cream is sometimes made of sour milk to which soda has been added. A pinch of soda added to tomato soup neutralizes the acid of the tomatoes and prevents curdling of the milk.

If to the neutral solution an extra portion of base is added, so that there is an excess of base over acid, the neutralization is overbalanced and the red paper turns blue. If to the neutral solution an extra portion of acid is added, so that there is an excess of acid over base, the neutralization is overbalanced in the opposite direction, and the solution acquires acid characteristics.

Most acids and bases will eat and corrode and discolor, while neutral substances will not. Soaps are very nearly neutral substances and are the safest cleansing agent for laundry, bath, and general work. Cheap soaps are carelessly prepared and are

apt to have an excess of the base ; but the better soaps are carefully prepared and are either neutral or only slightly alkaline.

Soap. — If we gather together scrapings of lard, butter, bits of tallow from burned-out candles, scraps of waste fat, or any other sort of grease, and pour a strong solution of lye over the mass, a soft soapy substance is formed. In colonial times, every family made its own supply of soap, utilizing, for that purpose, household scraps often regarded by the housekeeper of to-day as worthless. Grease and fat were boiled with water and hardwood ashes, which are rich in lye, and from the mixture came the soft soap used by our ancestors. In practice, the wood ashes were boiled in water, which was then strained off, and the resulting filtrate, or lye, was mixed with the fats for soap making. The fats contain fatty acids which neutralize the lye and form a new substance, soap.

With the advance of civilization the labor of soap making passed from the home to the factory, very much as bread making has done in our own day. Different varieties of soaps appeared, of which the hard soap was the most popular, owing to the ease with which it could be transported. Within the last few years liquid soaps have come into favor, especially in schools, railroad stations, and other public places, where a cake of soap would be handled by many persons. By means of a simple device (Fig. 59), the soap escapes from a receptacle when needed. The mass of the soap does not come in contact with the skin, and the spread of contagious skin diseases is lessened.

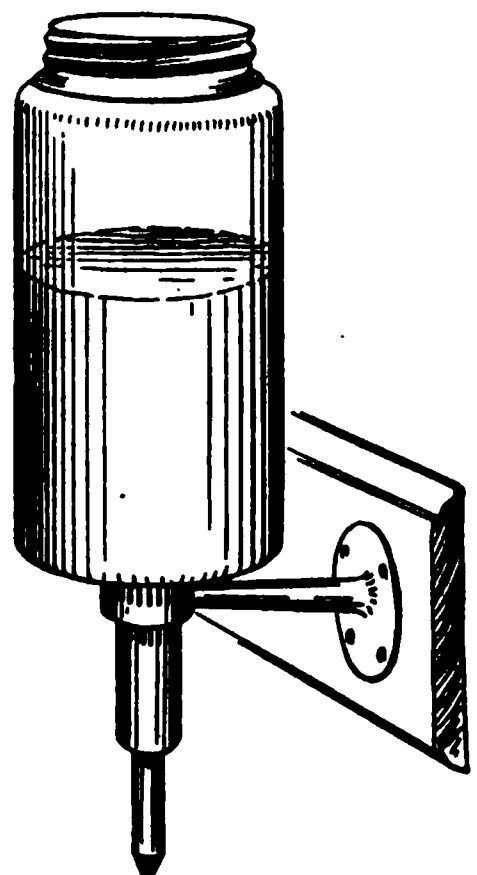


FIG. 59. — Liquid soap container.

Commercial soaps are made from a great variety of substances, such as tallow, lard, castor oil, coconut oil, and olive oil; very cheap soaps are made from rosin, cottonseed oil, and waste grease. The fats which go to waste in our garbage could be made a source of income, not only to the housewife, but to the city. In New York, Columbus, and some other cities garbage is used as a source of revenue; the grease from the garbage being sold for soap making, and the tankage for fertilizer.

Why soap cleans. — The natural oil of the skin catches and retains dust and dirt, and makes a greasy film over the body. This cannot be removed by water alone, but if soap is used and a generous lather is applied to the skin, the dirt is “cut” and passes into the water. Soap affects grease and water very much as the white of an egg affects oil and water. Oil and water do not mix, the oil remaining separate on the surface of the water. But if a small quantity of white of egg is added to oil and water an emulsion is formed and the oil separates into minute droplets which spread through the water. In the same way, soap acts on a grease film, separating it into minute droplets which leave the skin and spread through the water, carrying with them the dust and dirt particles. The warmer the water, the better will be the emulsion, and the more effective the removal of dirt and grease. This explanation holds true for the removal of grease from any surface, whether of the body, clothing, furniture, or dishes.

Washing powders. — Sometimes soap refuses to form a lather and instead cakes and floats as a scum on the top of the water. This is not the fault of the soap but of the water. As water seeps through the soil or flows over the land, it absorbs substances which modify its character and which, in some cases, render it almost useless for household purposes. Most of us are familiar with the rain barrel of the country house, and know

that the housewife prefers rain water for laundry and general work. Rain water, coming as it does from the clouds, is free from the chemicals gathered by ground water, and is practically pure. While foreign substances do not necessarily injure water for drinking purposes, they often prevent soap from forming an emulsion. Under such circumstances the water is said to be hard, and soap used with it is wasted. Even if water is only moderately hard much soap is wasted. The substances which make water hard are calcium and magnesium salts. When soap is put into water containing either or both of these, it combines with the salts to form sticky insoluble scum. It is therefore not free to form an emulsion and to remove grease, and is valueless as a cleansing agent.

A slight amount of hardness in water does not seriously affect the cleansing value of soap for toilet purposes. But it does seriously lessen the efficiency of soap in laundry work. In the laundry much soap is needed, and even a slight loss in scum would mean vast waste of soap and money in a short time. The addition of washing soda, or sodium carbonate, to hard water softens it and makes it suitable for laundry purposes. Washing soda combines with calcium and magnesium and prevents them from uniting with soap. The soap is thus free to form an emulsion, just as in soft water. In some cities where the water is very hard, as in Columbus, Ohio, it is softened and filtered at public expense, before it leaves the reservoirs. But even under these circumstances, a moderate use of washing powder is general in laundry work.

Washing powder is often strongly alkaline. If it is put on clothes dry, or is thrown into a crowded tub, it will eat the clothes. The only safe method is to dissolve the powder before the clothes are put into the tub. The trouble with many laundries is that they are careless about this and do not dissolve the powder before mixing it with the clothes.

Borax is a mild base and makes a good washing powder for fine work.

One of the most disagreeable consequences of the use of hard water for bathing is the unavoidable scum which forms on the sides of bathtub and washbowl. The removal of the caked grease is difficult, and if soap alone is used, the cleaning of the tub requires both patience and hard scrubbing. The labor can be greatly lessened by moistening the scrubbing cloth with turpentine and applying it to the greasy film, which immediately dissolves and thus can be easily removed. The presence of the scum can be largely avoided by adding a small amount of liquid ammonia to the bath water.

To remove stains from cloth. — While soap is, generally speaking, the best cleansing agent for the removal of grease, there are occasions when other substances can be used to better advantage. For example, grease spots on carpet and non-washable dress goods are best removed by the application of gasoline, benzine, or other strong grease solvents. These substances dissolve the grease, but do not remove it from the clothing; for that purpose a woolen cloth should be laid under the stain in readiness to absorb the benzine and the grease dissolved in it. If the grease is not absorbed while in solution, it remains in the clothing and after the evaporation of the benzine it reappears in full force. Carbona dissolves grease and can therefore be used to remove grease stains. Unlike gasoline and benzine, it is not inflammable and, for that reason, is a safe cleansing agent.

Cleaners frequently clean suits by laying a blotter over a grease spot and applying a hot iron; the grease, when melted by the heat, takes the easiest way of spreading itself and passes from the cloth to the blotter.

Paints are a mixture of oil and mineral matter. The oil ingredient can be removed by a strong grease solvent, such as

gasoline or benzine, and the mineral coating which remains can be brushed off when it becomes dry. The best solvent for paint is turpentine, and it is commonly used to remove paint spots from carpets, floors, metals, woodwork, etc. The paint scattered by careless workmen is the source of hopeless trouble to the housewife unless she is familiar with the solvent power of turpentine.

Fruit stains are caused by acids which are present in the fruit and which can be neutralized by weak bases like ammonia and borax. Linen spotted with fruit stains can be cleansed by soaking in weak ammonia or borax.

Iron is easily acted upon by acids and iron rust spots can be removed by acids. A little lemon juice placed on iron rust stain will frequently take it out. After the lemon juice has acted, salt should be rubbed over the spot in order to counteract any unused lemon juice. If the rust spots are very bad, a stronger acid such as hydrochloric acid is needed. In this case a strong base such as ammonia should be applied as a neutralizing agent after the acid action.

The tarnish which forms on silver is due to sulphur. When the sulphur, which is in the air, comes in contact with silver, it reacts with it to form a thin, dark coating of silver sulphide. If salt is rubbed over tarnished silver, it reacts with the silver sulphide and forms with it a substance which is soluble in ammonia. Tarnished silver, therefore, can be cleansed by rubbing with salt and rinsing in ammonia. If silver is washed daily in warm soapy water and rubbed dry, the silver sulphide does not have opportunity to gather in a coating, and the silver remains untarnished. Silver polish is used by most housekeepers for cleaning silver. It is usually a mass of finely pulverized chalk, containing some chemical such as salt which when rubbed against silver removes the coating of tarnish.

CHAPTER XIII

BAKING POWDERS AND SODA

Salts. — A neutral liquid formed by the action of hydrochloric acid and caustic soda solution (p. 142) has a brackish salty taste, and is, in fact, a solution of common salt. This can be demonstrated by evaporating the neutral liquid to dryness. The residue of solid matter proves to be common salt.

When an acid is mixed with a base, the result is a substance more or less similar in its properties to common salt; for this reason all compounds formed by the neutralization of an acid and a base are called salts. If, instead of hydrochloric acid (HCl), we use an acid solution of potassium tartrate, and if instead of caustic soda we use bicarbonate of soda (baking soda), the result is a brackish liquid as before, but the salt in the liquid is not common salt, but Rochelle salt. Different combinations of acids and bases produce different salts. Not all salts are absolutely neutral; some of them have an excess of alkali material and others have an excess of acid. Of all the vast group of salts the most abundant as well as the most important is common salt, known technically as sodium chloride because of its two constituents, sodium and chlorine.

We are not dependent upon neutralization for the enormous quantities of salt used in the home and in commerce. It is from the active, restless seas of the present, and from the dead seas of the prehistoric past that our vast stores of salt come. The waters of the Mediterranean and of our own Great Salt Lake are led into shallow basins, where, after evaporation by the heat of the sun, they leave a residue of salt.

By far the largest quantity of salt, however, comes from the seas which no longer exist, but which in far remote ages dried up and left behind them their burden of salt. Deposits of salt formed in this way are found scattered throughout the world, and in our own country are found in greatest abundance in New York state. The largest salt deposit known has a depth of one mile and exists in Germany.

Salt is indispensable on our table and in our kitchen, but the amount of salt used in this way is far too small to account for a yearly consumption of 4,000,000,000 tons in the United States alone. The manufacture of soap, glass, bleaching powders, baking powders, washing soda, and other chemicals depends on salt, and it is for these that the salt beds are mined.

Baking soda. — Salt is by all odds the most important sodium compound. Next to it come the so-called carbonates of sodium, that is, compounds of sodium in which carbon is present: first, sodium carbonate, or washing soda; and second, sodium bicarbonate, or baking soda. Washing soda is a compound of sodium, carbon, and oxygen. Baking soda is a compound of sodium, hydrogen, carbon, and oxygen. These are both obtained by treating salt with ammonia and carbon dioxide.

Since baking powder in some form is used in almost all homes for the raising of cake and pastry dough, it is essential that its helpful and harmful qualities be clearly understood.

The raising of dough by baking soda — bicarbonate of soda — is a very simple process. When soda is heated it gives off carbon dioxide gas. You can easily prove this for yourself by heating a little soda in a test tube, and testing the escaping gas in a test tube of lime water. When flour and water alone are kneaded and baked in loaves, the result is a mass so compact and hard that human teeth are almost powerless to crush and chew it. The problem is to separate the mass of dough or, in other words, to cause it to rise and lighten. This can be

done by mixing a little soda in the flour, because the heat of the oven causes the soda to give off bubbles of gas, and these in expanding make the heavy mass slightly porous. Bread is never lightened with soda because the amount of gas thus given off is too small to convert heavy compact bread dough into a spongy mass; but biscuit and cake, being less compact and heavy, are sufficiently lightened by the gas given off from soda.

There is one great objection, however, to the use of soda alone as a leavening agent. After baking soda has lost its carbon dioxide gas, it is no longer baking soda, but is transformed into washing soda. Sodium carbonate has a disagreeable taste and is by no means desirable for the stomach. But man's knowledge of chemicals and their effect on each other has enabled him to overcome this difficulty and, at the same time, to retain the leavening effect of the baking soda.

Baking powders. — If some cooking soda is put into lemon juice, vinegar, or other acid, bubbles of gas form and escape from the liquid. After the effervescence has ceased, a taste of the liquid will show you that the lemon juice has lost its acid nature, and has acquired in exchange a salty taste. Baking soda, when treated with an acid, is transformed into carbon dioxide and a salt. The various baking powders on the market to-day consist of baking soda and some acid substance, which acts upon the soda, forces it to give up its gas, and at the same time unites with the residue to form a harmless salt.

Cream of tartar contains sufficient acid to act on baking soda, and is a convenient and safe ingredient for baking powder. When soda and cream of tartar are mixed dry, they do not react on each other, neither do they combine rapidly in *cold* moist dough, but as soon as the heat of the oven penetrates the doughy mass, the cream of tartar combines with the soda and sets free the gas needed to raise the dough. The gas expands with the heat of the oven, raising the dough still

more. Meanwhile, the dough itself is influenced by the heat and is stiffened to such an extent that it retains its inflated shape and spongy nature.

Many housewives look askance at ready-made baking powders and prefer to bake with soda and sour milk, soda and buttermilk, or soda and cream of tartar. Sour milk and buttermilk are quite as good as cream of tartar, because the lactic acid which they contain combines with the soda and liberates carbon dioxide, and forms a harmless residue in the dough. In cakes made with molasses, cream of tartar is not needed, since the molasses contains sufficient acid to liberate carbon dioxide from the soda. If you examine a cookbook, you will see that soda is never used without an acid. We do not always recognize the presence of an acid, but it is always present, either as the acid of sour milk, fruit juices, cream of tartar, buttermilk, or molasses.

The desire of manufacturers to produce cheap baking powders led to the use of cheap acids and alkalies, regardless of the character of the resulting salt. For this reason many states have prohibited the use of ingredients known to be harmful. For a time alum was thought to be injurious in baking powder, but the best scientists now maintain that its product, after the process of digestion, is not harmful.

It is not only important to choose the ingredients carefully; it is also necessary to calculate the quantities of each, otherwise there will be an excess of acid or alkali for the stomach to take care of. A standard powder contains twice as much of cream of tartar as of bicarbonate of soda. The thrifty housewife can make for herself, at small cost, as good a baking powder as any on the market, by mixing cream of tartar and soda in the above proportions and adding a little cornstarch to keep the mixture dry.

The self-raising flour, so widely advertised by grocers, is flour in which these ingredients, or their equivalent, have been mixed by the manufacturer.

Soda mints. — Bicarbonate of soda is the main ingredient of the soda mints sold for indigestion. These correct a tendency to sour stomach because they counteract the surplus acid in the stomach, and form with it a safe neutral substance.

Seidlitz powder is a simple remedy consisting of two powders, one containing bicarbonate of soda, and the other, some acid, such as cream of tartar. When these substances are dissolved in water and mixed, effervescence occurs, carbon dioxide escapes, and a solution of Rochelle salt remains.

Source of soda. — An enormous quantity of sodium carbonate, or soda, as it is usually called, is needed in the manufacture of glass, soap, bleaching powders, and other commercial products. Formerly, the supply of soda was very limited because man was dependent upon natural deposits and upon the ashes of sea plants for it. Common salt, sodium chloride, is abundant, and in 1775 a prize was offered to any one who would find a way to obtain soda from salt. As a result of this offer, soda was soon manufactured from common salt. In the most recent method of manufacture, salt water, ammonia, and carbon dioxide are made to react, and baking soda is formed from the reaction. The baking soda is then heated and decomposes into washing soda, or the soda of commerce.

CHAPTER XIV

YEAST AND BREAD MAKING

WHILE baking powder is universally used for biscuits and cake, it is seldom, if ever, used for bread, because it does not furnish sufficient gas to lighten the tough heavy mass of bread dough. Then, too, most people prefer the taste of yeast-raised bread. There is a reason for this widespread preference, but to understand it, we must go somewhat far afield, and must study not only the bread of to-day, but the bread of antiquity, and the wines as well.

If grapes are crushed, they yield a liquid which tastes like the grapes; but if the liquid is allowed to stand in a warm place, it loses its original character, and begins to ferment, becoming, in the course of a few weeks, a strongly intoxicating drink. This is true not only of grape juice but also of the juice of other sweet fruits; apple juice ferments to cider, currant juice to currant wine, etc. This phenomenon of fermentation is known to practically all races of men, and there is scarcely a savage tribe without some kind of fermented drink. In the tropics the fermented juice of the palm tree serves for wine; in the desert regions, the fermented juice of the century plant; and in still other regions, the root of the ginger plant is pressed into service.

The fermentation which occurs in bread making is similar to that which is responsible for the transformation of plant juices into intoxicating drinks. The former process is not so old, however, since the use of alcoholic beverages dates back to the very dawn of history, and the authentic record of raised or leavened bread is but little more than 3000 years old.

The bread of antiquity. — The original method of bread making and the method employed by savage tribes of to-day is to mix crushed grain and water until a paste is formed, and then to bake this over a camp fire. The result is a hard compact substance known as unleavened bread. A considerable improvement over this tasteless mass is self-raised bread. If dough is left standing in a warm place a number of hours, it swells up with gas and becomes porous, and when baked, is less compact and hard than unleavened bread. Exposure to air and warmth brings about changes in dough as well as in fruit juices, and alters the character of the dough and the bread made from it. Bread made in this way would not seem palatable to civilized man of the present day; accustomed, as he is, to delicious bread made light and porous by yeast; but to the ancients, the least softening and lightening was welcome, and self-fermented bread, therefore, supplanted the original unleavened bread.

Soon it was discovered that a pinch of this fermented dough acted as a starter on a fresh batch of dough. Hence, a little of the fermented dough was carefully saved from a batch, and when the next bread was made, the fermented dough, or leaven, was worked into the fresh dough and served to raise the mass more quickly and effectively than mere exposure to air and warmth could do in the same length of time. This use of leaven for raising bread has been practiced for ages.

Grape juice mixed with millet ferments quickly and strongly, and the Romans learned to use this mixture for bread raising, kneading a very small amount of it through the dough.

The cause of fermentation. — Although alcoholic fermentation, and the fermentation which goes on in rising dough, were known and utilized for many years, the cause of the phenomenon was a sealed book until the nineteenth century. About that time it was discovered, through the use of the microscope,

that fermenting liquids contain an army of minute plant organisms which not only live there, but which actually grow and multiply within the liquid. For growth and multiplication, food is necessary, and this the tiny plants get in abundance from the fruit juices; they feed upon the sugary matter and as they feed, they ferment it, changing it into carbon dioxide and alcohol. The carbon dioxide, in the form of small bubbles, passes off from the fermenting mass, while the alcohol remains in the liquid, giving the stimulating effect desired by users of alcoholic drinks. The unknown strange organisms were called yeast, and they were the starting point of the yeast cakes and yeast brews manufactured to-day on a large scale, not only for bread making but for the commercial production of beer, ale, porter, and other intoxicating drinks.

The grains, rye, corn, rice, wheat, from which meal is made, contain only a small quantity of sugar; on the other hand, they contain a large quantity of starch which is easily convertible into sugar. Upon this the tiny yeast plants in the dough feed, and, as in the case of the wines, ferment the sugar, producing carbon dioxide and alcohol. The dough is thick and sticky and the gas bubbles expand it into a spongy mass. The tiny yeast plants multiply and continue to make alcohol and gas, and in consequence, the dough becomes lighter and lighter. When it has risen sufficiently, it is kneaded and placed in an oven; the heat of the oven soon kills the yeast plants and drives the alcohol out of the bread; at the same time it expands the imprisoned gas bubbles and causes them to lighten and swell the bread still more. Meanwhile, the dough has become stiff enough to support itself. The result of the fermentation is a light, spongy loaf.

Where does yeast come from? — The microscopic plants that we call yeast are widely distributed in the air, and float around there until chance brings them in contact with a

substance favorable to their growth, such as fruit juices or moist warm batter. Under favorable conditions of abundant moisture, heat, and food, they grow and multiply rapidly, and cause the phenomenon of fermentation. Wild yeast settles on the skin of grapes and apples, but since it does not have access to the fruit juices within, it remains inactive very much as a seed does before it is planted. But when the fruit is crushed, the yeast plants get into the juice, and feeding on it, grow and multiply. The stray yeast plants which get into the sirup are relatively few, and fermentation is often slow; it requires several weeks for currant juice to ferment, and several months for the juice of grapes to be converted into wine.

Stray yeast finds a favorable soil for growth in the warmth and moisture of a batter; but although the number of these stray plants is very large, it is insufficient to cause rapid fermentation, and if we depended upon wild yeast for bread raising, the result would not be to our liking.

When our remote ancestors saved a pinch of dough as leaven for the next baking, they were actually cultivating yeast, although they did not know it. The reserved portion served as a favorable breeding place to the yeast plants within it. They grew and reproduced amazingly, and became so numerous that the small mass of old dough in which they were gathered served to leaven the entire batch at the next baking.

As soon as man learned that yeast plants caused fermentation, he realized that it would be to his advantage to cultivate yeast and to add it to bread and to plant juices rather than to depend upon accidental and slow fermentation from wild yeast. Shortly after the discovery of yeast in the nineteenth century, man commenced his attempt to cultivate the tiny organisms. Their microscopic size added greatly to his trouble, and it was only after years of careful

and tedious investigation that he was able to perfect the commercial yeast cakes and yeast brews universally used by bakers and brewers. The well-known compressed yeast cake is simply a mass of live and vigorous yeast plants, embedded in a soft, soggy material, and ready to grow and multiply as soon as they are placed under proper conditions of heat, moisture, and food. Seeds which remain on our shelves do not germinate, but those which are planted in the soil do. So it is with the yeast plants. While in the cake, they are as inactive as the seed; when placed in dough, or fruit juice, or grain water, they grow and multiply and cause fermentation.

CHAPTER XV

BLEACHING, BLUEING, STARCHING

THE beauty and the commercial value of uncolored fabrics depend upon the purity and perfection of their whiteness; a man's white collar and a woman's white waist must be pure white, without the slightest tinge of color. But all natural fabrics, whether they come from plants, like cotton and linen, or from animals, like wool and silk, contain more or less coloring matter, which impairs the whiteness. This coloring not only detracts from the appearance of fabrics which are to be worn uncolored, but it seriously interferes with the action of dyes, and at times plays the dyer strange tricks.

Natural fibers, moreover, are difficult to spin and weave unless some softening material such as wax or resin is rubbed lightly over them. The matter added to facilitate spinning and weaving generally detracts from the appearance of the uncolored fabric, and also interferes with successful dyeing. Thus it is easy to see that the natural coloring matter and the added foreign matter must be entirely removed from fabrics destined for commercial use. Exceptions to this general rule are sometimes made, because unbleached material is cheaper and more durable than the bleached product, and for some purposes is entirely satisfactory. Unbleached cheesecloth and sheeting are frequently purchased in place of the more expensive bleached material. Formerly, the only known bleaching agent was the sun's rays, and linen and cotton were put out to sun for a week; that is, the unbleached fabrics were spread on the grass and exposed to the bleaching action of sun and dew.

An artificial bleaching agent. — While the sun's rays are effective as a bleaching agent, the process is slow; moreover, it would be impossible to expose to the sun's rays the vast quantity of fabrics used in the civilized world of to-day. The huge and numerous bolts of material which daily come from our looms and factories must therefore be whitened by artificial means. The substance almost universally used as a rapid artificial bleaching agent is chlorine, best known to us as a constituent of common salt. Chlorine is never free in nature, but is found in combination with other substances, as, for example, in combination with sodium in salt, or with hydrogen in hydrochloric acid.

Free chlorine is obtained by pouring hydrochloric acid over potassium permanganate crystals and gently heating the mixture. The gas which forms is chlorine.

How chlorine bleaches. — Chlorine is an active substance and combines readily with most substances, but especially with hydrogen. If chlorine comes in contact with steam, it abstracts the hydrogen and unites with it to form hydrochloric acid, but it leaves the oxygen free and uncombined. This tendency of chlorine to combine with hydrogen makes it valuable as a bleaching agent. In order to test the efficiency of chlorine as a bleaching agent, drop a wet piece of colored gingham or calico into a bottle of chlorine, and notice the rapid disappearance of color from the sample. If unbleached muslin is used, the moist strip loses its natural yellowish hue and becomes a clear, pure white. The explanation of the bleaching power of chlorine is that the chlorine combines with the hydrogen of the water and sets oxygen free; the uncombined free oxygen oxidizes the coloring matter in the cloth and destroys it.

Chlorine has no effect on dry material, as is seen when we put dry gingham into the jar; this is because there is no water

to furnish hydrogen for combination with the chlorine, and no oxygen is set free.

Bleaching powder. — Chlorine gas has a very injurious effect on the human body, and cannot be used directly as a bleaching agent. It attacks the mucous membrane of the nose and lungs, and produces the effect of a severe cold or catarrh, and when inhaled, causes death. But certain compounds of chlorine are harmless, and can be used for destroying either natural or artificial dyes. One of these compounds, namely chloride of lime, is one of the most important bleaching agents of commerce. It comes in the form of powder, which can be dissolved in water to form the bleaching solution in which the colored fabrics are immersed. But fabrics immersed in a bleaching powder solution do not lose their color as would naturally be expected. The reason for this is that the chlorine gas is not free to do its work, but is restricted by its combination with the other substances. By experiment it has been found that the addition to the bleaching solution of an acid, such as vinegar or lemon juice or sulphuric acid, causes the liberation of the chlorine. The chlorine thus set free reacts with the water and liberates oxygen; this in turn destroys the coloring matter in the fibers, and transforms the material into a bleached product.

The acid used to liberate the chlorine from the bleaching powder, and the chlorine also, rot materials with which they remain in contact for any length of time. For this reason, fabrics should be removed from the bleaching solution as soon as possible, and should then be rinsed in some solution, such as ammonia, which is capable of neutralizing the harmful substances. Finally the fabric should be thoroughly rinsed in water in order that all foreign matter may be removed. The reason home bleaching is so seldom satisfactory is that most amateurs fail to realize the necessity of immediate neutrali-

zation and rinsing, and allow the fabric to remain too long in the bleaching solution, and allow it to dry with traces of the bleaching substances present in the fibers. Material treated in this way is thoroughly bleached, but is at the same time rotten and worthless. Chloride of lime is frequently used in laundry work; the clothes are whiter than when cleaned with soap and simple washing powders, but they soon wear out unless the precaution has been taken to add an "antichlor" or neutralizer to the bleaching solution.

Commercial bleaching. — In commercial bleaching the material to be bleached is first moistened with a very weak solution of sulphuric acid or hydrochloric acid, and is then

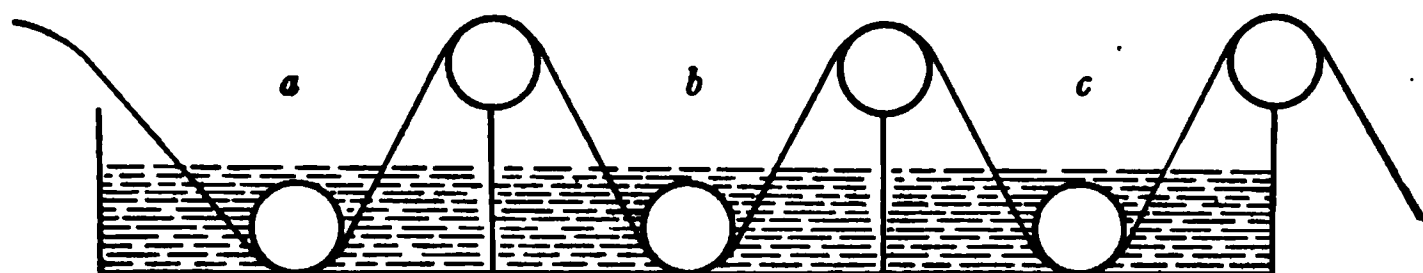


FIG. 60. — The material to be bleached is drawn through an acid *a*, then through a bleaching solution *b*, and finally through a neutralizing solution *c*.

immersed in the bleaching powder solution. As the moist material is drawn through the bleaching solution, the acid on the fabric acts upon the solution and releases chlorine. The chlorine liberates oxygen from the water. The oxygen in turn attacks the coloring matter and destroys it.

The bleached material is then immersed in a neutralizing bath and is finally rinsed thoroughly in water. Strips of cotton or linen many miles long are drawn by machinery into and out of the various solutions (Fig. 60), are then passed over pressing rollers, and emerge snow white, ready to be dyed or to be used as white fabric.

Wool and silk bleaching. — Animal fibers like silk, wool, and feathers, and some vegetable fibers like straw, cannot be bleached by means of chlorine, because it attacks not only the

coloring matter but the fiber itself, and leaves it shrunken and inferior. Cotton and linen fibers, apart from the small amount of coloring matter present in them, contain nothing but carbon, oxygen, and hydrogen, while animal fibers contain in addition to these elements some compounds of nitrogen. The presence of these nitrogen compounds influences the action of chlorine and produces unsatisfactory results. For animal fibers it is necessary to discard chlorine as a bleaching agent, and to substitute a substance which will have a less disastrous action upon the fibers. Such a substance is to be had in sulphurous acid. When sulphur burns, as in a match, it gives off disagreeable fumes, and if these are made to bubble into a vessel containing water, they dissolve and form with the water a substance known as sulphurous acid. That this solution has bleaching properties is shown by the fact that a colored cloth dipped into it loses its color, and that unbleached fabrics immersed in it are whitened. The harmless nature of sulphurous acid makes it very desirable as a bleaching agent, especially in the home.

Silk, lace, and wool when bleached with chlorine become hard and brittle, but when whitened with sulphurous acid, they retain their natural characteristics.

This mild form of bleaching substance has been put to uses which are now prohibited by the pure food laws. In some canneries common corn is whitened with sulphurous acid, and is then sold under false representations. Cherries are sometimes bleached and then colored with the bright shades which under natural conditions indicate freshness.

Bleaching with chlorine is permanent, the dyestuff being destroyed by the chlorine. But bleaching with sulphurous acid is temporary, because the milder bleach does not actually destroy the dyestuff, but merely modifies it, and in time the natural yellow color of straw, cotton, and linen reappears. The

yellowing of straw hats during the summer is familiar to every one; the straw is merely resuming its natural color which had been modified by the sulphurous acid applied to the straw when woven.

Why the color returns. — Some of the compounds formed by the sulphurous acid bleaching process are gradually decomposed by sunlight. In consequence the original color is slowly restored. The portion of a hat protected by the band retains its fresh appearance because the light does not reach it. Silks and other fabrics bleached with sulphurous acid fade with age, and assume an unnatural color. One reason for this is that the dye used to color the fabric requires a clear white background, and loses its characteristic hues when its foundation is yellow instead of white. Then, too, dyestuffs are themselves more or less affected by light, and fade slowly under a strong illumination.

Materials which are not exposed to an intense and prolonged illumination retain their whiteness for a long time, and hence dress materials and hats which have been bleached with sulphurous acid should be protected from the sun's glare when not in use.

The removal of stains. — Bleaching powder is very useful in the removal of stains from white fabrics. Ink spots rubbed with lemon juice and dipped in bleaching solution fade away and leave on the cloth no trace of discoloration. Sometimes these stains can be removed by soaking in milk, and where this is possible, it is the better method.

Bleaching solution, however, while valuable in the removal of some stains, is unable to remove paint stains, because paints owe their color to mineral matter, and on this chlorine is powerless to act.

Blueing. — No matter how carefully material is bleached in the mills, and how white it is when purchased, it slowly

yellows with age. Our grandmothers kept their sheets, curtains, tablecloths, and underwear white by spreading them on the grass after washing and allowing the sun to rebleach them. The modern housewife lacks the large yard in which to spread clothes for rewhitening by the sun. Most public laundries dry their wash indoors, and are absolutely dependent upon chemicals for whitening it. Bleaching powders are frequently used to whiten goods, but unless the powders are carefully used and are well neutralized, they rot and weaken the fabrics and wear out the clothes.

A safe way to avoid the yellowish tinge in clothes is to use blueing. Blue has the property of neutralizing yellow and produces the effect of white. Yellow clothes can be made white by dipping in blue water. If they are very yellow a strong solution of blueing is needed to make them appear white to the eye; if they are only slightly yellow, a weaker solution serves to whiten them.

Clothes that are to be blued must be carefully rinsed and free from soap before they are dipped in blueing water, because soap takes blue quickly and makes bluish streaks over the clothes. Soap also reacts upon some blues to form substances which stain the clothes and give them a disagreeable color.

Ultramarine, a good blue. — One of the best blues is ultramarine, a coloring matter which has been used for years by painters. Originally it was very expensive, because it was obtained only from lapis lazuli, a rare mineral called sapphire by the ancients. To-day it is produced in large quantities very cheaply by chemical processes. The best way to use ultramarine is to put it in a bag of fine material, and to suspend the bag in water; the ultramarine then spreads evenly through the water and gives a uniform tint.

Ultramarine is not affected by air and light and clothes blued with it retain their whiteness well; it is not affected by alkalies,

and soap which has escaped rinsing does not react with it to form spots and stains. For this reason ultramarine is one of the most satisfactory blues which can be used. Indigo is also a safe and satisfactory dye. Like ultramarine, it is not affected by either alkalies or light and is widely used in laundry work.

Prussian blue, a poor blue. — This blue is a compound of iron, carbon, and nitrogen. It is cheaper than ultramarine, but is correspondingly inferior. It is an intense blue and is so strong in color that 600 pounds of white lead can be tinged by one pound of it. Prussian blue is objectionable in laundry work largely because it is easily decomposed by washing soda and soap. Many a laundress who does not hang her clothes on rusty hooks, and who uses only clean rope clotheslines, is surprised and annoyed by iron rust spots on her clothes, and by the bad color of the wash in general. This is explained by the fact that Prussian blue when decomposed liberates iron.

Starching. — Starch, as well as blue, is an important article in laundry work. Without starch collars and cuffs would be soft and would crumple easily; pillow cases would not give the fine appearance they do to the bed; sash curtains would be flimsy and would soil quickly, and table linen would lack its gloss. Even articles which are usually thought of as unstarched, frequently have a little starch in them; for example, fine lace collars are often dipped in thin starch for a mild stiffening, and ruchings, edgings, and frills are usually treated in the same way.

There are two ways of preparing starch for laundry work: the cold-water process and the hot-water process. Cold or raw starch is made by stirring starch in cold water until the liquid has a strong milky appearance. Starch does not dissolve in cold water, but if it is stirred in the water its granules spread through the liquid and become suspended in it, forming starch water. Clothes placed in the water soak up enough starch to become very stiff on drying.

Hot-water starch is made by moistening starch with cold water and then slowly stirring into it sufficient boiling water to make a transparent paste. Under the influence of heat and moisture the little sacs which hold the starch burst and set the starch free. The starch which is set free mingles with the water and forms a clear transparent paste which hardens to a jelly on cooling. When this starchy substance is put on material, it causes the fibers to cling firmly together and stiffens the clothes. Collars, cuffs, shirts, and materials which need to be very stiff should be dipped in raw starch; laces, curtains, and dresses which require less stiffening should be dipped in hot-water starch. A strong glaze can be secured by adding a pinch of borax to cold starch, and a pinch of borax or a lump of paraffin to hot starch.

The strength of raw starch and the thickness of the starch paste vary with the materials to be starched. For fine materials a thin starch is best, because a thick starch would stiffen them to the tearing point. For thick, closely woven materials a thin starch is also needed, because the heavy and numerous fibers would absorb too much thick starch and become too stiff. But, for coarse and loosely woven materials a thick starch is necessary, because the loose threads absorb little water and secure little starch.

Sources of starch. — Laundry starch is obtained mainly from corn and potatoes, although some is made from damaged wheat, and a small amount of the highest grade is made from rice. Starch is composed of microscopic granules, which vary greatly in shape and size in different plants; those of the potato are shell-shaped and nearly twice as large as the round, lens-shaped granules of wheat starch; rice granules are less than one tenth the size of potato granules; the granules of corn are smaller than those of wheat, but larger than those of rice. The stiffening power of starch depends largely upon the size of the granules,

because small granules can penetrate further than large ones and be more thoroughly absorbed by the fabric. Rice, because of the minuteness of its granules, yields the best laundry starch, but this is expensive and is used only for the finest materials. Corn is abundant in the United States and its starch granules are small; the laundry starch made from corn is very good and is very widely used in this country. Potato starch, because of the ease and cheapness with which it can be manufactured, is also widely used, though inferior to the starch made from rice or corn.

Potato starch is made by shredding or rasping potatoes in water and then straining the entire mass through a fine sieve.



FIG. 61.—Magnified starch granules: 1. Potato. 2. Wheat. 3. Rice.

Only the minute starch granules and the water escape through the small openings of the sieve. The escaping starch and water run into vats and are left undisturbed there until the starch settles to the bottom and the water can be drained off. The caky starch mass is then dried and broken into lumps or ground into powder.

CHAPTER XVI .

DYES

Dyes. — One of the most important and lucrative industrial processes of the world to-day is that of staining and dyeing. Whether we consider the innumerable shades of leather used in shoes and harnesses and upholstery; the multitude of colors in the paper which covers our walls; the artificial scenery which adorns the stage and by its imitation of trees and flowers and sky translates us to the Forest of Arden; or whether we consider the uncounted varieties of color in dress materials, in carpets, and in hangings, we are dealing with substances which owe their beauty to dyes and dyestuffs.

The coloring of textile fabrics, such as cotton, wool, and silk, far outranks in amount and importance that of leather, paper, and the like; hence the former only will be considered here. But the theories and facts relative to textile dyeing are applicable in a general way to all other forms as well.

Plants as a source of dyes. — Among the most beautiful examples of man's handiwork are the baskets and blankets of the North American Indians, woven with a skill which cannot be equaled by manufacturers, and dyed in mellow colors with a few simple dyes extracted from local plants. The magnificent rugs and tapestries of Persia and Turkey, and the silks of India and Japan, give evidence that a knowledge of dyes is widespread and ancient. Until recently, the vegetable world was the source of practically all coloring matter, the pulverized root of the madder plant yielding the reds, the leaves and stems of the indigo plant the blues, the heartwood

of the tropical logwood tree the blacks and grays, and the fruit of certain palm and locust trees yielding the soft browns. So great was the commercial demand for dyestuffs that large areas of land were given over to the exclusive cultivation of the more important dye plants. Vegetable dyes are now, however, rarely used because about the year 1856 it was discovered that dyes could be obtained from coal tar, the thick sticky liquid formed as a by-product in the manufacture of coal gas. These artificial coal tar, or aniline, dyes have practically undisputed sway to-day.

Wool and cotton dyeing. — If a piece of wool is soaked in a solution of a coal tar dye, such as magenta, the fiber of the cloth draws some of the dye out of the solution and absorbs it, becoming in consequence beautifully colored. The coloring matter becomes “part and parcel,” as it were, of the wool fiber, because repeated washing of the fabric fails to remove the newly acquired color; the magenta coloring matter unites chemically with the fiber of the wool, and forms with it a compound insoluble in water, and hence fast to washing.

But if cotton is used instead of wool, the acquired color is very faint and washes off readily. This is because cotton fibers possess no chemical substance capable of uniting with the coloring matter to form a compound insoluble in water.

That vegetable fibers, such as cotton and linen, act differently toward coloring matter from animal fibers, such as silk and wool, is not surprising when we consider that the chemical natures of the two groups are very different. Vegetable fibers contain only oxygen, carbon, and hydrogen, while animal fibers always contain nitrogen in addition, and in many cases sulphur as well.

The selection of dyes. — There are, of course, many exceptions to the general statement that animal fibers dye readily and vegetable fibers poorly, because certain dyes fail utterly

with woolen and silk material and yet are fairly satisfactory when applied to cotton and linen fabrics. Then, too, a dye which will color silk may not have any effect on wool, in spite of the fact that wool, like silk, is an animal fiber; and certain dyestuffs to which cotton responds most beautifully are absolutely without effect on linen.

The nature of the material to be dyed determines the coloring matter to be used; in dyeing establishments a careful examination is made of all textiles received for dyeing, and the particular dyestuffs are then applied which long experience has shown to be best suited to the material in question. Where "mixed goods," such as silk and wool, or cotton and wool, are concerned, the problem is a difficult one, and the countless varieties of gorgeously colored mixed materials give evidence of high perfection in the art of dyeing and weaving.

Housewives who wish to do successful home dyeing should therefore not purchase dyes indiscriminately, but should select the kind best suited to the material, because the coloring principle which will remake a silk waist may utterly ruin a woolen skirt or a linen suit.

Indirect dyeing. — The varied uses to which dyed articles are put make fastness of color absolutely necessary. A shirt, for example, must not be discolored by perspiration, nor a waist faded by washing, nor a carpet dulled by sweeping with a dampened broom. In order to insure permanency of dyes, an indirect method was originated which consisted of adding to the fibers a chemical capable of acting upon the dye and forming with it a colored compound insoluble in water, and hence "safe." For example, cotton material dyed directly in logwood solution has almost no value, but if it is soaked in a solution of oxalic acid and alum until it becomes saturated with the chemicals, and is then transferred to a logwood bath, the color acquired is fast and beautiful.

This method of indirect dyeing is known as the mordanting process: it consists of saturating the fabric to be dyed with chemicals which will unite with the coloring matter to form compounds unaffected by water. The chemicals are called mordants. This process is chiefly used with cotton goods.

How variety of color is secured. — The color which is fixed on the fabric as a result of chemical action between mordant and dye is frequently very different from that of the dye itself. Logwood dye when used alone produces a reddish brown color of no value for either beauty or permanence; but if the fabric to be dyed is first mordanted with a solution of alum and oxalic acid and is then immersed in a logwood bath, it acquires a beautiful blue color.

Moreover, since the color acquired depends upon the mordant as well as upon the dye, it is often possible to obtain a wide range of colors by varying the mordant used, the dye remaining the same. Fabrics immersed directly in alizarin acquire a reddish yellow tint. When, however, they are mordanted with certain aluminium compounds they acquire a brilliant Turkey red; when mordanted with chromium compounds, a maroon; and when mordanted with iron compounds, the various shades of purple, lilac, and violet.

Color designs in cloth. — It is thought that the earliest attempts at making "fancy materials" consisted in painting designs on a fabric by means of a brush. In more recent times the design was cut in relief on hard wood, the relief being then daubed with coloring matter and applied by hand to successive portions of the cloth.

The most modern method of design making is that of machine or roller printing. In this, the relief blocks are replaced by engraved copper rolls which rotate continuously and in the course of their rotation automatically receive coloring matter on the engraved portion. The cloth to be printed is drawn uniformly

over the rotating roll, receiving color from the engraved design; in this way, the color pattern is automatically printed on the cloth with perfect regularity. In cases where the fabrics do not unite directly with the coloring matter, the design is supplied with a mordant and the impression made on the fabric is that of the mordant. Then the fabric is transferred to a dye bath and the mordanted portions, represented by the design, unite with the coloring matter and form the desired color patterns.

Unless the printing is well done, the coloring matter does not thoroughly penetrate the material, and only a faint blurred design appears on the back of the cloth; the gaudy designs of cheap calicoes and gingham often do not show at all on the under side. Such carelessly made prints are not fast to washing or light, and soon fade. But in the better grades of material the printing is well done, the color designs are fairly fast, and a little care in the laundry suffices to eliminate any danger of fading.

Color designs of the greatest durability are produced by the weaving together of colored yarns. When yarn is dyed, the coloring matter penetrates to every part of the fiber, and hence the patterns formed by the weaving together of well-dyed yarns are very fast to light and water.

If the color designs to be woven in the cloth are intricate, complex machinery and skillful handwork are necessary; hence, patterns formed by the weaving of colored yarns are expensive and less common than printed fabrics.

CHAPTER XVII

METALS USED IN THE HOME

The value and source of metals. — If you examine a skyscraper which is being built, you will see that its framework is metal; if you examine the new railroad coaches and Pullmans which traverse the country, you will see that they, too, are metal. Metal wires carry our telephone and telegraph messages; metal tracks guide our trolley cars and railroad engines; metal pipes convey water and gas from reservoir to consumer; metal stoves cook our food and metal utensils hold it; metal coins serve as money. Metals are among the most important substances known, and in proportion as man has used them, in just that proportion has civilization advanced. As long as stone and wood implements and utensils served man's needs, he remained savage, or at most, semicivilized.

Metals are obtained from ores. — Sometimes metals such as copper and gold are found in the earth as metals, and can be mined directly and put into use. More often they exist in combination with other substances. Tin, for example, does not occur in the earth as tin, but it occurs in combination with oxygen as tin oxide. Tin oxide is mined and the metal tin is then extracted from it. Lead does not occur in the earth as lead, but in combination with sulphur as lead sulphide. Lead sulphide is mined and the lead is then extracted from it. Minerals rich in metals are called ore.

Iron is always obtained from iron ore by smelting, that is, by heating. When broken iron ore, coal, and limestone are heated together in a blast furnace (Fig. 62) the iron melts and

collects in a receptacle at the bottom of the furnace. From there, the molten iron is drawn off into molds where it cools and solidifies as pig or cast iron. The limestone combines with the impurities in the ore and with the ashes of the coal, and forms slag. Molten slag is lighter than molten iron, and floats on top of the iron. The molten slag can therefore be drawn off into separate vessels.

Iron. — Iron is the most useful of all metals, and it is also one of the most widely distributed metals. The United States is particularly rich in iron ore, producing about 50,000,000 tons yearly.

Iron is an extremely strong metal and can support a tremendous weight, and it is so rigid that it can withstand the fiercest gale. Our modern skyscrapers, our smaller factories, and office buildings have frameworks of iron, and are thus able to withstand the mechanical forces of destruction. Iron is superior to all other metals for bridges, piers, and building

FIG. 62. — A blast furnace.

supports. Railings, rails, coaches, farm implements, anchors, nails, chains, bolts, wires, and hundreds of other necessary articles are made of this metal.

There are different kinds of iron for different purposes. The iron which forms the kitchen stove is different from that which makes the horseshoe, and from the iron or steel which composes the Pullman coach. The pig iron which comes from the blast furnace is not pure, but contains about 5 per cent of carbon, and small quantities of phosphorus and sulphur. Pig iron which contains so much carbon cannot be forged or hammered into different shapes, but must be poured into molds. When it solidifies, it expands and fills up the mold, and makes excellent castings. The phosphorus and sulphur present in pig iron make it brittle; hence while cast iron is strong, it cannot be used in places where it is subject to great shock.

The forms of iron that can endure the greatest shock are wrought iron and steel, both of which are obtained from cast iron. Wrought iron is made by heating cast iron in a furnace until it has lost practically all of its impurities. It is tough but soft, and is easily hammered or welded into any desired shape, such as horseshoes and links of chains. It can be rolled into sheets and plates and drawn out into wires.

Steel is more important than either cast iron or wrought iron. It contains practically no impurities except carbon; and it contains more carbon than wrought iron, but less than cast iron. Steel is stronger and more durable than either of the other forms of iron. It is so elastic that it forms the finest springs in watches, and it is so resistant that it is used for the cutting edge of tools and machines.

Copper. — The earliest implements and utensils used by man were of stone, and the long years in which he depended solely upon stone weapons and stone devices make up what is known as the stone age. Gradually man learned to fashion crude utensils from copper, a reddish metal which he found scattered over the earth. The hard, tough, flexible copper was easily softened by heat and fashioned into forms suitable for primi-

tive man's simple needs. As civilization advanced and man's requirements increased, copper was put to more and more various purposes. To-day not only are our kettles, heaters, and boilers made of copper, but the trolley wires and our telephone and telegraph wires are also of copper. The very books which we read are printed from copper plates, and the materials which we wear are designed from copper rolls. New metals have been discovered and mined and used extensively, but none has replaced copper.

A disadvantage of copper is that it is affected by moisture in the air, and becomes covered with a green layer. Corroded copper is similar in character to rusted iron, both processes being due to oxidation in a moist atmosphere. To prevent corrosion, a protective covering is applied to the metal.

Acids, such as fruit juices and vinegar, act readily upon copper and form compounds which are injurious to the body. For this reason copper cooking utensils are unsafe. Iron is also acted upon by acids, but the compounds formed are not so injurious to the body as the copper compounds.

In addition to the free copper which is scattered abundantly over the earth, there is considerable copper in ore. But not until years after free copper was extensively used, did man learn to extract metals from their ores.

Tin. — Tin is a silvery white metal. It is seldom found free, and then only in small quantities. The ore from which it is extracted is found in England, Australia, and India. Tin is soft and malleable and can be beaten into thin sheets. These tin sheets are called tin foil, and are used as a covering for chocolate and other foods, and as a lining for candy, soap, and cigar boxes. The so-called tin pan of the kitchen is not a real tin pan; if it were, it would be too soft for use. It is an iron pan that has been dipped into melted tin, and has acquired a tin coating (Fig. 63). The bright, shiny, clean appearance

of the metal makes it popular for utensils. In ordinary air, tin does not rust like iron or corrode like copper, and hence tin-lined utensils require less care than copper and iron ones. Rust forms on pans wherever the tin coating is scratched or worn so as to expose the iron beneath. The coating wears off

FIG. 63. — Tinning fire extinguishers.

most easily at seams and edges, and rust usually appears there first. Tin is a good lining for metal containers in which canneries "put up" their products because it is not affected by the weak acids in fruits and vegetables.

Zinc. — This metal, like tin, is whitish and has a good luster. The most important use of zinc is in the manufacture of galvanized iron. Zinc wears better than tin as a coating on iron that is exposed to the weather or to rough usage. Telegraph

wires, barbed wire, iron for various household and industrial uses, are galvanized, or dipped into molten zinc.

Zinc is an important element in the battery which furnishes the electrical current for ringing our doorbells.

Lead. — The pipes which bring water to our homes and which carry away the wastes are usually of lead. The metal is soft and can be easily bent and cut by the plumber. Lead is rolled into sheets and used as a lining of tea chests and tea cans, and as a lining for tanks and cisterns. Sometimes it is rolled into fine sheets and used as lead foil. It is also made into bullets and shot, and mixed with tin to form solder.

Compounds of lead are poisonous to the body. Lead is acted upon by acids, even those which are present in dilute form in foods, and the compounds formed from the reaction are dangerous. For this reason, cooking utensils should not be made of lead, and should not be soldered together, since solder contains lead.

Ordinary water acts very slowly upon lead, and hence water which flows rapidly through lead pipes is not injured. But if water remains undrawn in pipes for long periods, the lead is continuously acted upon, and dangerous compounds may accumulate in the water. After vacations, however short, water should be allowed to run freely until all pipes are completely empty of their standing water. The fresh supply will be safe.

Water which contains carbon dioxide and organic matter acts upon lead, and rapidly forms compounds injurious to health. When the city's water supply contains these substances, lead pipes cannot be used with safety. Either the water supply must be abandoned and a new source found, or different pipes must be installed.

Alloys. — Very often different metals are melted together to form new substances or alloys more suited to our needs. The wonderful bronze busts and ornaments are made of an alloy,

for bronze is simply a mixture of copper, tin, and zinc. Brass is a mixture of copper and zinc; and pewter, a mixture of lead and tin.

Pure metals are rarely used. Pure gold is so soft that it cannot endure constant use. An 18-carat ring is not pure gold, because one fourth of it is copper, but it is the purest gold which is consistent with daily wear. The best grade steel contains a little nickel for added hardness. Motor boats, steam turbines, and torpedo boats are not made from ordinary steel, but from steel alloyed with nickel. The silver coins which serve as money are alloyed with copper for hardness.

Aluminium. — One of the most important metals to the modern housewife is aluminium, because it is made into silvery pots

FIG. 64. — Lightweight camp cooking outfit for Boy Scouts.

and pans that are light, durable, and attractive (Fig. 64). Aluminium cooking utensils are serviceable and safe, as well as attractive, because they do not rust or corrode, and are not affected by dilute vegetable acids. Pure aluminium is acted upon by acids, but aluminium which has been exposed to the air acquires a dull coating of aluminium oxide which is not affected by acids. Aluminium cooking utensils should not be polished or cleaned with anything which wears off the protective coating. Soap and water clean aluminium sufficiently.

Aluminium is very widely used for purposes such as the tops of preserve jars, powder boxes, small picture frames, and many useful and ornamental objects. When aluminium is ground and mixed with oil it forms a durable paint which can be spread over other metals as a protection. Cheerful, silvery looking letter boxes, fire signals, lamp-posts, and radiators owe their bright appearance to aluminium paint. The only drawback to the use of aluminium is its high cost, because it is not cheap, in spite of the fact that it exists abundantly in all parts of the earth. It is expensive because it is always in combination with substances from which it cannot be easily extracted. Common clay is a compound of aluminium, and attempts have been made to obtain aluminium from it, but the process is difficult and has not been commercially successful. The source of most of our aluminium is aluminium oxide.

The characteristics of metals. — If the average person were asked to describe metals, he would doubtless say that they were hard, heavy, opaque substances capable of enduring enormous strain and of being beaten into various shapes, or of being drawn out into fine wire. This definition would be true of the familiar metals, such as gold, silver, copper, and iron, because all of these metals are hard, heavy, and opaque. All of them are also more or less tenacious; that is, they offer strong resistance to being torn apart and stand great strain before they give way.

It is the tensile strength of metals which makes them useful in cables, suspension bridges, and large buildings. The familiar metals are all more or less malleable, that is, they can be beaten out by hard blows. Gold can be hammered, or beaten, into sheets less than one hundred thousandth of an inch thick. Iron is not so malleable as gold. All the common metals are also ductile, that is, they can be drawn out into fine wire. Few metals are as ductile as gold, one grain of which can be drawn out into a thread almost a mile long.

The familiar metals answer to the above description, but other metals, like sodium, potassium, and calcium, do not. We need some chemical guide to determine what is and what is not a metal.

Any element which will combine with oxygen and hydrogen to form a base is a metal, no matter what its physical appearance may be. Metal sodium when put into water unites with oxygen and hydrogen to form the base sodium hydroxide, or caustic soda. The metal potassium unites with oxygen and hydrogen to form the base potassium hydroxide, or lye.

The unfamiliar metals. — The metal sodium is never found free, but it is found almost everywhere in combination. Its most abundant compound is common salt. Large deposits of another compound, sodium nitrate or Chile saltpeter, occur in Chile, and sodium silicate is present in many rocks. The unfamiliar metals, potassium and calcium, are little used in the pure state, but their compounds are very important.

The most important compound of the metal calcium is calcium carbonate, of which marble and limestone are good examples. Marble and limestone are used as building stones, and limestone is also used in the manufacture of lime, without which we could have no whitewash, cement, or mortar. Limestone is heated in strong furnaces until it is transformed to quicklime. Water is then placed on the lumps of quicklime, which swell and finally crumble to a powder called slaked lime. The greatest use of slaked lime is the making of mortar and cement, and the removing of hair from skins which are to be tanned and made into leather.

If a small quantity of the slaked lime is dissolved in water and the solution is filtered, it forms the lime water often prescribed by physicians for sour stomach. If a large quantity of the slaked lime is placed in water, much of it does not dissolve, but remains suspended in the water. Water full of suspended lime particles is called whitewash and is used to coat the walls of cellars and sheds.

CHAPTER XVIII

OILS, PAINTS, AND VARNISHES

The preservation of wood and metal. — The decaying of wood and the rusting of metal are due to the action of air and water; when wood and metal are surrounded by a covering which air and moisture cannot penetrate, decay and rust do not occur. Oils, paints, varnishes, enamels, and lacquers form protective coverings for wood and metal. Keys and machines rust in damp weather but oiled keys and machines remain free of rust; unpainted fences rot, but fences carefully painted from time to time remain in good condition for years; it has long been known that the best way to keep a house in good repair is to paint it regularly. An iron bedstead is enameled not only for the sake of appearance, but also as a protection against iron rust. The metal fixtures of automobiles and boats are always lacquered or varnished or protected in some way from the air and moisture to which they are constantly exposed. If this protective coating is scratched or rubbed off, the metal begins to rust.

Oils. — There are two kinds of oils. One kind does not dry when it is spread over a surface but remains smeary; for example, lard, cottonseed oil, and olive oil. The other kind dries when it is spread over a surface and forms a tough hard coating; for example, linseed oil and hemp oil. Oil which is put on machinery as an aid to smooth running must be a non-drying oil. Oil which is rubbed over furniture to protect it and to improve its appearance must be a rapidly drying oil. All oil which is used in paints must be of the quickly drying kind.

Non-drying oils are cheaper than drying oils because they are more abundant. The important non-drying oils are palm, coconut, and Japan oils obtained from plants; black fish oil, porpoise oil, and whale oil obtained from the blubber of black fish, porpoises, and whales; cod-liver oil obtained from the liver of the codfish; and neat's-foot oil made by boiling the feet and bones of cattle in water. Vaseline and lubricating oils are mineral oils obtained from the distillation of crude petroleum.

The most important drying oils are linseed, hemp, and poppy oils extracted by pressure from the seeds of the flax, hemp, and poppy plants. Oils from corn, cotton, and rape seeds dry out very slowly, but they are not really satisfactory as drying oils. Linseed oil is the most desirable of the drying oils and about thirty-five million gallons of it are used annually in the United States.

Paints. — Paint is a mixture of linseed oil and white lead, or of linseed oil and some other metallic compound. White lead is a heavy white powder which mixes readily with linseed oil, and is then easily spread over a surface, giving a white coating. White lead spreads well and is durable, but it is extremely poisonous and demands constant care on the part of the painter. Frequently painters are made ill by careless handling of white lead paints. Another objection to white lead is its tendency to blacken in the presence of sulphurous gases.

When paint is spread on a surface in a thin coat, the linseed oil rapidly absorbs oxygen from the air, hardens, and forms a tough film with the lead. A thick coating does not dry quickly and tends to peel off; for this reason it is better to give a surface several thin coatings of paint rather than a single heavy one. Zinc white, or zinc oxide, is sometimes substituted for lead, but it requires more oil for mixing and spreading, and since linseed oil is expensive, zinc white is less in demand than white lead.

For the sake of ornamentation paints of various colors are in demand. Paints are colored by mixing pigments, or coloring substances, with the white lead and oil. These coloring substances are usually metallic compounds; for example, Brunswick green is a metallic compound made by soaking copper in salt water containing certain sulphates; yellow ocher is an oxide of iron. Some of the brightest and most beautiful pigments are formed when lead unites with oxygen to form lead oxides. Black paints are usually obtained by stirring lampblack or finely ground charcoal with the white lead and linseed oil. A pigment much used for pleasing effects by photographers and water color artists is sepia. This coloring substance is obtained from a sac in the cuttlefish, and is, in fact, the substance which is thrown out by the fish when it is disturbed, and which serves to blacken the water around the fish.

The pigments which are stirred into the paints are not dissolved in the oil, but are suspended in it in a finely divided state. These minute particles are spread with the paint. When the paint dries, they are caught and held in the tough skin, and give color to the surface which the film covers.

Varnish and shellac. — Almost every home has linseed oil with which to rub down dingy furniture, to refinish worn and scratched household articles, and to brighten floors and fixings. When linseed oil alone is rubbed over a surface it dries to a hard tough film and serves as a protection, but it does not give any marked brilliancy to the surface. The protective coating formed by varnish, on the other hand, is brilliant and glossy, as well as hard and tough, and is more desirable for many purposes. Varnish is made by putting melted rosin in boiling linseed oil. When the mixture has cooled, turpentine is added until the mass becomes thin enough to spread with a brush.

Occasionally varnish is made by dissolving resin in alcohol. The alcohol evaporates and leaves a brilliant but brittle film

which readily cracks and peels off. The best varnishes are made from rosin and linseed oil. Well-varnished furniture will retain its good appearance for years if it is occasionally wiped with a woolen rag moistened with linseed oil varnish. This is also the best method of removing finger marks and grease from fine furniture, such as pianos and cabinets. Locomotives and exposed machines are usually coated with a varnish made by dissolving pitch in turpentine; such a varnish is durable but is not desirable for furniture and indoor decorations.

If white lead is added to varnish, the so-called white enamel paints result; and if, in addition, coloring matter is added, the colored enamels result.

Shellac is obtained by dissolving in alcohol resins obtained from certain East India trees. Many different trees in East India are infected by insects which puncture the bark, feed upon the sap, and leave an incision through which exudes a light yellow resinous matter. After sufficient of the resinous matter has collected on the trees it is gathered and sold as lac. Liquid shellac is a solution of lac in alcohol; it is not so durable as varnish and is therefore less used. Varnish and shellac should always be applied lightly and allowed to dry thoroughly. If the coating is thick, it dries slowly, sticks, and finally peels off.

Lacquer is obtained by dissolving in alcohol or turpentine the sap of a small Japanese tree.

Creosote oil for wood blocks. — Railroad ties and street paving blocks are protected by a cheap oil rather than by paint. Wood is soaked in creosote oil until it becomes thoroughly saturated with the oily substance. The pores of the wood are thus closed to the entrance of air and moisture, and decay is avoided. Creosote is poisonous to insects and to many animals, and thus acts as a protection against them. Wood treated with creosote is very durable. Creosote oil is obtained from the destructive distillation of coal and wood.

CHAPTER XIX

NITROGEN AND ITS RELATION TO PLANTS

Nitrogen. — A substance which plays an important part in animal and plant life is nitrogen. Soil and the fertilizers which enrich it, the plants which grow on it, and the animals which feed on these, all contain nitrogen or nitrogenous compounds. The atmosphere, which we ordinarily think of as a storehouse of oxygen, contains far more nitrogen than oxygen, since four

fifths of its whole weight is made up of this element. On examining nitrogen we find that it is colorless, odorless, and tasteless. If the oxygen in a vessel filled with air is made to unite with some other substance, nitrogen remains. This can be done by floating on water a dish containing phosphorus, then igniting the phosphorus, and

FIG. 65. — Preparing nitrogen.

placing an inverted jar over the burning substance (Fig. 65). The phosphorus in burning unites with the oxygen of the air and the gas that remains in the jar is chiefly nitrogen.

Plant food. — Food is the source of energy in every living thing and is essential to both animal and plant life. Plants get their food from the lifeless matter which exists in the air and in the soil, while animals get their food from plants. It is true that man and many other animals eat fleshy foods and

depend upon them for partial sustenance, but the ultimate source of all animal food is plant life, since meat-producing animals live upon plants.

Nitrogen is absolutely necessary to plant life and growth. Since a vast store of nitrogen exists in the air, it would seem that plants should never lack for this food. But most plants are unable to make use of the boundless store of atmospheric nitrogen, because they do not possess the power of abstracting nitrogen from the air. For this reason, they have to depend solely upon nitrogenous compounds which are present in the soil and are soluble in water. These soluble nitrogenous soil compounds are absorbed by the roots of the plant.

The poverty of the soil. — Plant roots are constantly taking nitrogen and its compounds from the soil; the soil becomes poorer in nitrogen and finally possesses too little to support vigorous and healthy plant life. The fertility of the soil can be restored if we add to it a fertilizer containing nitrogen compounds which are soluble in water. Decayed vegetable matter contains large quantities of nitrogen compounds, and if decayed vegetation is placed upon soil it acts as a fertilizer, returning to the soil what was taken from it. Since man and all other animals subsist upon plants, their bodies likewise contain nitrogenous substances, and manure and waste animal matter is valuable as a fertilizer or soil restorer.

Bacteria as nitrogen gatherers. — Soil from which crops are removed year after year usually becomes less fertile, but the soil from which crops of clover, peas, beans, or alfalfa have been removed becomes richer in nitrogen rather than poorer. This is because the roots of these plants have on them tiny swellings, or tubercles, in which millions of bacteria live and multiply (Fig. 66). These bacteria have the remarkable power of taking free nitrogen from the air in the soil and of combining it with other substances to form compounds which plants can use. The

bacteria-made compounds dissolve in the soil water and are absorbed into the plant by the roots. So much nitrogen-containing material is made by the root bacteria of plants of the pea family that the soil in which they grow becomes richer in nitrogen, and if plants which cannot make nitrogen are planted in such a soil, they find there a store of it. A crop of peas, beans, or clover is equivalent to fertilizer and helps to make the soil ready for other crops.

FIG. 66. — Roots of soy bean having tubercle-bearing bacteria.

Artificial fertilizers. — Plants need other foods besides nitrogen, and they exhaust the soil not only of nitrogen, but also of phosphorus and potash. There are many other substances absorbed from the soil by the plant, such as iron, sodium, calcium, magnesium, but these are used in smaller quantities and the supply in the soil does not readily become exhausted (Fig. 67).

Commercial fertilizers generally contain nitrogen, phosphorus, and potash in amounts varying with the requirements of the soil. Wheat requires a large amount of phosphorus and quickly exhausts the ground of that food-stuff; a field which has supported a crop of wheat is poor in phosphorus, and a satisfactory fertilizer for that field must contain a large percentage of phosphorus.

The amount of fertilizer needed by the farmers of the world is enormous, and the



FIG. 67. — Water cultures of buckwheat: 1, with all the food elements; 2, without potash; 3, without nitrates.

problem of securing the necessary substances in quantities sufficient to satisfy the demand bids fair to be serious. But modern chemistry is at work on the problem, and already it is possible to make commercially some nitrogen compounds suitable for absorption by plant roots.

Phosphorus is obtained from bone ash and from phosphate rock which is widely distributed over the surface of the earth. Bone ash and thousands of tons of phosphate rock are treated with sulphuric acid to form a phosphorus compound which is soluble in soil water and usable by plants.

The other important ingredient of most fertilizers is potash. Wood ashes are rich in potash and are a valuable addition to the soil. But the amount of potash thus obtained is far too limited to supply the needs of agriculture; and for many years the main sources of potash have been the vast deposits of potassium salts found in Prussia.

Although Germany up to 1915 furnished the American farmer with the bulk of his potash, it will probably not do so in the future. In 1911 an indirect potash tax was levied by Germany on her best customer, the United States, to whom 15 million dollars' worth of potash had been sold the preceding year. This led Americans to inquire whether potash could not be obtained at home. When the German supply was cut off by the Great War, the search for other supplies was redoubled.

Geologists say that long ages ago an ocean covered Germany, that the waters of the ocean slowly evaporated, and that the various substances in the sea water were deposited on the ocean bed in thick layers. The deposits thus left by the evaporation of the sea water gradually became hidden by sediment and soil, and lost to sight. From such deposits, potash is obtained. Geologists tell us that some of our own land in the West was once covered by an ocean, and that most of the waters evaporated and disappeared from it very much as they did from

Germany. Therefore valuable deposits of potash probably exist there, and a thorough search is being made for them. The Great Salt Lake of Utah is a relic of that western ocean, and works have been established for extracting potash from its waters.

Another source of potash is seaweed, especially the giant kelp, which absorbs large quantities of potash from sea water. The kelps are abundant, covering thousands of square miles in the Pacific Ocean, from Mexico to the Arctic Ocean. Works have been established for recovering potash from this source.

Much potash is obtained from the mineral wastes of cement making and other industries.

Manure. — The oldest and best known fertilizer is manure, the excreta or waste matter of animals, and before the days of commercial fertilizers the farmer depended solely upon stable or barnyard manure for the improvement of his soil. Manure is very valuable, since every ton of it contains about ten pounds of nitrogen, eight pounds of potassium, two and one half pounds of phosphorus, and small quantities of lime, magnesia, and other substances needed by worn-out soil. Manure should not be heaped in the barnyard because much of its valuable material seeps into the soil and is lost. In addition, exposed manure heaps ferment and become sour. A third argument against exposed barnyard manure is that it serves as a breeding place for flies and other obnoxious creatures. Modern stables in the city and model farms in the country have brick manure pits in which manure can be stored without loss from seepage or from fermentation.

Sewage, after chemical treatment, is likewise valuable as a fertilizer and some large cities sell for fertilizer the more solid portions of the sewage. It has been estimated that the sewage of England alone would be worth eighty million dollars annually as fertilizer. It is not improbable that in the future large cities will use sewage as a source of income.

CHAPTER XX

DRUGS AND PATENT MEDICINES

Stimulants and narcotics. — Man has learned not only the action of substances upon each other, such as bleaching solution upon coloring matter, washing soda upon grease, acids upon bases, but also the effect which certain chemicals have upon the human body.

Drugs and their varying effects upon the human system have been known to mankind from remote ages. In the early days, familiar leaves, roots, and twigs were steeped in water to make medicines. In more recent times, however, these simple herb teas have been replaced by complex drugs, compounded not only from innumerable plant products, but from animal and mineral matter as well. Quinine, rhubarb, and arnica are examples of purely vegetable products; iron, mercury, and arsenic are equally well known as distinctly mineral products, while cod-liver oil is the most familiar illustration of an animal remedy. Ordinarily a combination of products best serves the ends of the physician.

Substances which like cod-liver oil serve as food to a worn-out body, or like iron tend to enrich the blood, or like quinine aid in bringing an abnormal system to a healthy condition, are valuable servants and cannot be entirely dispensed with so long as man is subject to disease.

Some substances, like opium, laudanum, and alcohol, are not required by the body as food, or as an aid to recovery, but are taken for the stimulus they arouse or for the insensibility they induce. These are harmful to man and cannot be used by

him without mental, moral, and physical loss. Substances of this class are known as narcotics and stimulants.

The cost of health. — In the physical as in the financial world, nothing is to be had without a price. Vigor, endurance, and mental alertness are bought by hygienic living; that is, by proper food, fresh air, exercise, cleanliness, and reasonable hours. Some people wish vigor and endurance, but are unwilling to live the life which will develop these qualities. Plenty of sleep, exercise, and simple food lay the foundations of health. Many, however, are not willing to take the care necessary for healthful living, because it would force them to sacrifice some of the hours of pleasure. Sooner or later, these pleasure-seekers begin to feel tired and worn, and some of them turn to drugs and narcotics for artificial strength. At first the drugs seem to restore the lost energy, and without harm; but the cost soon proves to be one of the highest nature ever demands.

The uncounted cost. — The first and most obvious effect of opium, for example, is to deaden pain and to arouse pleasure; but while the drug is producing these soothing sensations, it interferes with bodily functions. Secretion, digestion, absorption of food, and the removal of waste matters are hindered. Continued use of the drug leads to headache, exhaustion, nervous depression, and heart weakness. There is thus a heavy toll reckoned against the user, and the creditor is relentless in demanding payment.

The respite allowed by a narcotic is brief, and a depression inevitably follows. In order to overcome this depression, another dose is taken, and as time goes on, the intervals of depression become more frequent and the necessity to overcome them increases. Soon one is a victim of the drug. The sanatoria of our country are crowded with people who are trying to free themselves from a drug habit into which they have unintentionally drifted. What is true of opium is equally true of other narcotics.

The right use of narcotics. — In the hands of the physician, narcotics are a great blessing. In some cases, by relieving pain, they give the body necessary rest. Only those who know of the suffering endured in former times can fully appreciate the decrease in pain brought about by the proper use of narcotics.

Patent medicines, cough sirups. — A physician regards the permanent welfare of his patient and administers carefully chosen and harmless drugs. Mere medicine venders ignore the good of mankind, and flood the market with cheap patent preparations which injure the purchaser, but bring millions of dollars to the manufacturer. Practically all patent, or proprietary preparations contain a large proportion of narcotics or stimulants.

Among the most common ailments of both young and old are coughs and colds; and many patent cough mixtures are on the market. Such "quick cures" almost invariably contain one or more narcotic drugs. They do not relieve the cold permanently, but do occasion subsequent disorders. Even lozenges and pastilles are not free from fraud, but have a goodly proportion of narcotics, containing in some cases chloroform and morphine.

The widespread use of patent cough medicines is due largely to the fact that many persons avoid consulting a physician about so trivial an ailment as an ordinary cold, and attempt to doctor themselves.

Catarrh is a very prevalent disease in America, and numerous catarrh remedies have been devised, most of which contain the harmful drug, cocaine. Laws have been enacted which require on the labels a statement of the drugs used and the amounts. But the great mass of people are ignorant of the harmful nature of certain drugs and do not even read the label, or if they do glance at it, fail to comprehend the dangerous nature of the drugs specified. In order to safeguard the uninformed pur-

chaser and to restrict the manufacture of harmful patent remedies, the sale of preparations containing narcotics should be limited.

Soothing sirups; soft drinks. — The development of a race is limited by the mental and physical growth of its children, and yet thousands of children are annually stunted and weakened by drugs, because most colic cures, teething concoctions, and soothing sirups are merely agreeably flavored drug mixtures. Those who have used such preparations know that a child usually becomes fretful and irritable between doses, and can be quieted only by larger and more frequent supplies. A habit formed in this way is difficult to overcome, and many a child when scarcely over its babyhood has a craving which in later years may lead to drug taking. Even though the drug craving is not created, considerable harm is done to the child, because its body is left weak and non-resistant to diseases of infancy and childhood.

Many of our soft drinks contain narcotics. The use of the coca leaf and the kola nut for such preparations has increased very greatly within the last few years, and doubtless legislation will soon be instituted against the sale of harmful soft drinks.

Headache powders. — The stress and strain of modern life cause many headaches. Work must be done and business attended to, and the average sufferer grasps at any remedy which removes the immediate pain. The relief afforded by most headache mixtures is due to antipyrine or acetanilide. These drugs weaken heart action, diminish circulation, reduce the number of red corpuscles in the blood, and bring on chronic anæmia. Pallid cheeks and blue lips are visible evidence of the too frequent use of headache powders.

The labels required by law are often deceptive and convey no adequate idea of the amount of drug consumed. For example, 240 grains of acetanilide to an ounce seems a small quantity of

drug for a headache powder, but when one considers that there are only 480 grains in an ounce, it will be seen that each powder is one half acetanilide. Powders taken in small quantities and at rare intervals are apparently harmless; but they never remove the cause of the trouble. Ordinarily, hygienic living will eliminate the source of the trouble; if it does not, a physician should be consulted.

Other deceptions. — Nearly all patent medicines contain some alcohol, and in many, the quantity of alcohol is far in ex-

FIG. 68. — Diagram showing the amount of alcohol in some alcoholic drinks and in one much used patent medicine.

cess of that found in the strongest wines. Tonics and bitters advertised as cures for spring fever and for a worn-out system are scarcely more than cheap cocktails, and the amount of alcohol in some widely advertised patent remedies is almost equal to that in strong whisky (Fig. 68).

Some conscientious persons who would not touch beer, wine, whisky, or any other intoxicating drink consume patent remedies containing large quantities of alcohol and thus unintentionally expose themselves to mental and physical danger.

CHAPTER XXI

HOW TO KEEP WELL WITHOUT DRUGS AND PATENT MEDICINES

EVERY year millions of people suffer from tuberculosis, pneumonia, typhoid fever, and diphtheria. Some recover entirely and regain full health and strength; others recover partially but are weakened for life; and still others die. Tuberculosis alone kills about 400 of our countrymen every day, and in its deadly work consumes more money than is spent on all the public schools of the country. Almost as many people are killed by pneumonia, and it causes even more intense suffering. Coughs, colds, and catarrh are considered homely and harmless diseases, but severe attacks of them often cause great discomfort and weakness, and temporary loss of work. Dangerous diseases, such as tuberculosis, pneumonia, typhoid fever, and diphtheria, as well as simpler ailments, such as coughs and colds, are due to special bacteria, which make their way into the body and live upon its tissues. Different types of bacteria are responsible for different diseases. Certain bacteria destroy lung tissue and cause pneumonia; other bacteria develop in the small intestine and produce typhoid fever; still other bacteria develop mainly in the respiratory organs, such as nose, throat, and pharynx, and cause influenza.

Bacteria that produce disease, like bacteria that spoil food, multiply rapidly, decompose the substances upon which they feed, and throw off poisonous secretions. Like the bacteria that produce decay, they are everywhere, but there are simple effective methods of protecting the body against disease, just as there are simple effective methods of protecting food against decay.

How bacteria get into the body. — Disease bacteria do not harm us so long as they remain outside the body, but as soon as they get into the body through the nose, mouth, wounds, or cuts they may develop and produce disease. Every cut or wound is an open door to bacteria, and the mouth and nose are permanent channels by which they enter. If milk from diseased cows or water from polluted rivers is drunk, multitudes of disease bacteria get into the body. If good food is handled with soiled hands, bacteria pass into the body with

FIG. 69. — Street sprinkler and sweeper.

the food. A drinking cup that is used by many people always has disease germs on it.

Bacteria are blown through the air, but finally settle with dust and dirt on exposed surfaces and remain there until disturbed by wind, sweeping, or dusting. The person who sweeps with a damp broom, and dusts with a damp cloth keeps down the dust and protects herself against bacteria. The city which sprinkles or flushes its streets with water before the street cleaners begin their sweeping, protects its citizens against unnecessary infection from bacteria (Fig. 69).

Disease bacteria come from sick people or from sick animals. The tuberculosis bacteria (or bacilli) in the air come from persons suffering from tuberculosis; the typhoid germs in water come from the bodies of typhoid patients. Tuberculosis germs are widespread because people suffering with tuberculosis carelessly spit on the street and on the floor. The spit, or sputum, together with the bacteria which it contains, dries and is scattered far and wide by the wind. If the bacteria get into the mouth or nose, they make their way to the lungs, stomach, and intestines. The pocket handkerchiefs and the towels used by a consumptive are full of germs, and should not be carelessly left around or shared with any one. A person suffering with tuberculosis should cover his mouth with his handkerchief when coughing or sneezing. If he does not, he fills the air with particles of moisture in which hundreds of bacilli live. There are almost innumerable ways in which bacilli are scattered from a sick person to a well person.

Typhoid bacteria live in the walls of the intestines of the patient and get into the waste matter discharged from the bowels. If this waste matter is not promptly disposed of, flies alight on it and carry away bacteria on their bodies. When these flies later alight on bread, sugar, and other substances they leave typhoid bacteria on the food. Sometimes the waste matter, or excreta, of typhoid patients is carried by pipes to a river. The river moves onward and carries the typhoid germs to remote regions. If we could prevent careless and unnecessary scattering of germs from sick people and animals we would eliminate many of the most dangerous diseases.

Common sense in overcoming bacteria. — The best way to keep ourselves well and resistant to germs is to eat plain wholesome food, to sleep long and in a well-aired room, to take as much fresh air and exercise as possible, to wear warm clothing

in winter and light clothing in summer, to avoid wet feet and damp clothing, to drink plenty of water, to wash often, to take rest and recreation when possible, and to avoid working on "nerves." Germs are everywhere, but a body in good condition overcomes them.

Even the healthiest bodies have weak moments. If they did not, tired feeling, depression, headache, indigestion, and backache would be unknown to them. Because healthy bodies have weak moments when germs may get the upper hand, and because even healthy bodies cannot kill germs if they come in too large numbers, and because there are many people who are never really strong, we must make every effort to kill germs and keep them away from us.

Killing germs in the home. — Disease-producing bacteria, like food-destroying bacteria, are killed by heat. If the sputum of a tubercular patient is burned and his bedding, towels, handkerchiefs are soaked in hot suds of boiling water, all tubercular germs are killed. In hospitals tubercular patients now use paper cups for sputum and sanitary paper handkerchiefs for the nose mucus. These cost very little and can be burned without loss. A great many people now use paper or cheese-cloth handkerchiefs when they have colds, since these cheap substitutes can be burned. If linen handkerchiefs are used, they should not be thrown into the common laundry to remain there for days and spread infection, but should be boiled at once and freed from germs. The spoon with which a sick child is given medicine or food should be washed in boiling water before it is used by any one else. The chances that disease will spread are greatly lessened when care is taken to disinfect by heat all articles of clothing, bedding, towels, and dishes.

Sunlight is a germ killer. — It has been shown conclusively that sunlight rapidly kills bacteria, and that it is only in

dampness and darkness that bacteria thrive and multiply. Dirt and dust exposed to the sunlight lose their living bacteria, while in damp cellars and dark corners the bacteria thrive, increasing steadily in number. For this reason our houses should be kept light and airy; blinds should be raised, even if carpets do fade. Is it not better that carpets and furniture should fade than that disease-producing bacteria should find a permanent abode in our dwellings? Kitchens and pantries in particular should be thoroughly lighted. Bedclothes, rugs, and clothing should be exposed to the sunlight as frequently as possible; there is no better safeguard against bacterial disease than light. In a sick room sunlight is especially valuable, because it not only kills bacteria, but keeps the air dry, and new bacteria cannot get a start in a dry atmosphere.

Bacteria are killed by certain chemicals. — Chloride of lime, burning sulphur, corrosive sublimate, carbolic acid, and formalin are disinfectants; that is, chemicals which kill bacteria. Chloride of lime is cheap, and a small amount of it poured into the closet bowl kills all bacteria and makes the excreta harmless. A surgeon about to perform an operation must have hands free of bacteria. He cannot dip his hands into boiling water to free them from bacteria, but he disinfects them with weak carbolic acid or a solution of corrosive sublimate. A solution of one part carbolic acid to twenty parts of water kills all germs and does not injure the skin.

Corrosive sublimate is the cheapest disinfectant, but it is very poisonous and must be carefully handled. A quarter of an ounce of corrosive sublimate in one quart of water makes an effective disinfectant and is used in hospitals for mopping floors, wiping walls, and dusting woodwork. To disinfect or fumigate a room formalin is generally used. When a room is to be fumigated, all drawers, closets, and wardrobes in the room are opened wide, the doors and windows are closed,

and the keyhole and cracks are stopped with paper or cotton. A pint of formaldehyde is mixed with six to eight ounces of potassium permanganate in a large bowl which is placed in a large metal pan. This is set in the middle of the room and the room kept closed for three or four hours. At the end of that time all bacteria are dead, and the room and its contents are absolutely safe.

Cuts, wounds, and sores. — A prick from a pin, a jag from a rusty nail, a cut from a knife, or a tear from a splinter often causes a painful sore, and sometimes even causes death from blood poisoning and lockjaw. This is because germs from the pin, nail, knife, or splinter remain in the opening and breed there. The bacteria which cause boils, erysipelas, blood poisoning, inflammation, and lockjaw are on everything, and the only way we can be sure to escape trouble from cuts and other wounds is to kill all bacteria promptly, and to protect the wound against the entrance of new bacteria. The bacteria from the instrument which causes the trouble, whether it be bullet, stone, or knife can be killed by bathing the opening with weak carbolic acid, turpentine, hydrogen peroxide, or other disinfectants. If the wound is a small cut or sore, a little carbolated vaseline rubbed over it will often kill the germs, and the wound can be protected against new bacteria by a soft clean cloth. A wound properly dressed, that is, thoroughly disinfected and carefully bound, does not fester and cause prolonged pain. A wound carelessly dressed causes prolonged severe pain and may lead to erysipelas, boils, blood poisoning, or even to death by lockjaw. If a cut or wound is small and bleeds freely, the flowing blood washes away most of the germs, and the white blood cells kill the few that remain. But it is better not to depend upon the blood and its corpuscles, because if the dangerous germs get a start, pus and inflammation set in, and the wound must be lanced, opened, and then thoroughly

disinfected. It is simpler and less painful to kill germs in a new wound than to open an inflamed, infected one.

The need of help from city and state. — Our health depends not only upon ourselves but also upon the city and state in which we live. If a city is careful about the sweeping of its streets, the removal of its garbage and sewage, the purity of its milk and water, the extermination of disease carriers, such as flies and rats, and the isolation, or quarantining, of all contagious cases, the people are quite free from most epidemics, and the death rate is low. If a city is careless about these things, many people suffer from contagious diseases and the death rate is high.

A city should clean its streets frequently and hygienically. Dust should not be stirred up. To keep down dust the streets should be sprinkled (Fig. 69, p. 197) or flushed before the sweeping is done. Sweeping dry streets with dry brooms merely stirs up germs and spreads them through the air. Vacant lots are a source of dust and germs, and should be converted into well-sodded grassy plots, because grass keeps down dust.

FIG. 70. — Metal waste can.

Horse manure, banana skins, apple cores left in the street for days serve as a breeding place for flies and other germ carriers; lost handkerchiefs, bits of paper, old rags accumulate and distribute dust and germs. Many cities place metal waste baskets or receptacles on the streets and encourage people to throw waste material into them rather than on the pavements (Fig. 70). Frequent cleaning of the streets and frequent removal of waste material from public receptacles are essential features of good city housekeeping.

Practically every house in town and city buys milk, and it is important that milk should be reasonably free of disease bacteria. But bacteria can be seen only with a strong and expensive microscope, and housewives and dealers have neither the money for microscopes nor the time for examination. It is the duty of the city to examine the milk and the sources from which it comes, and to forbid its sale if unclean and dangerous with germs. Most cities through their Board of Health keep strict supervision over the milk supply; health officers inspect the milk brought to the railroad stations and the milk brought in wagons from neighboring farms; they also inspect as frequently as possible the stores and dairies in which milk is sold at retail.

The health of a community depends upon its drinking water, which is usually taken from the nearest river or stream. It is impossible to obtain pure water direct from rivers and streams that flow through thickly settled regions, because the houses and factories that are situated on its banks and the boats that ply back and forth pour their refuse into the water. In innumerable ways a river is contaminated with disease germs. A city should filter its drinking water and thus provide its residents with a pure supply.

Prompt and scientific disposal of garbage should be looked after by the city. The garbage set out by the housewife and storekeeper should be promptly collected and removed in well-made covered wagons from which nothing can drop to the street. It should be then taken to garbage plants or factories and made into useful substances, such as fertilizer and soap. Under no circumstances should garbage be thrown on vacant lots.

Sewage. — Prompt and wise disposal of sewage is one of the most important duties of a community. By means of a network of pipes, the sewage of individual houses is taken to large tanks, called septic tanks, erected at public expense.

Some communities deodorize this sewage and make fertilizer of it. Other communities send it from the tanks into beds of gravel and sand through which it seeps (Fig. 71). Sewage which has been filtered by seepage through sufficient soil is harmless and can be discharged into streams and harbors without contaminating them. But large numerous beds are necessary. Many cities pay no attention to the proper disposal of sewage and send it into the streams unfiltered, thus endangering the health of the citizens.

FIG. 71. — Method of filtering sewage before discharging it into rivers.

In small towns and villages there is no common sewage system, and the individual house disposes of its own wastes. This is usually done by sending the waste matter through an underground pipe to a cesspool a short distance from the house. In time the cesspool fills up and must be cleaned out. Such a disposal of wastes is satisfactory unless the cesspool is near a well or other source of water. If the wastes spread through the ground and reach the well before they are purified by filtration, they contaminate the water and make it the carrier of disease. For absolute safety the cesspool of an ordinary house should be 75 feet from a well, and the cesspool of a country hotel should be much farther from the water supply (Fig. 72). The more people there are in a building, the more abundant

is the sewage and the larger is the plot of earth necessary to purify it. Every summer visitor to the country should investigate the source of the drinking water, and the method of disposing of the hotel sewage. If there is any possibility that the sewage drains into the well, the hotel should be abandoned.

FIG. 72. — Showing how drinking water can be contaminated from cesspool (c) and wash water (w).

Quarantine. — One of the duties of the Board of Health is to enforce the quarantine laws in order to protect people from unnecessary exposure to contagious diseases. The Board of Health requires physicians to report immediately to the health officers all cases of contagious diseases. As soon as a contagious disease, such as diphtheria, is reported, a conspicuous placard is placed on the house where the patient lives, and persons are forbidden to enter or to leave the house. The germs of many diseases like diphtheria are most active and apt to grow just after they leave the body of the patient; hence the greatest danger from these germs occurs in the neighborhood of the patient, either in the sick room or in the house. For this reason houses are quarantined.

If a single child in a household has diphtheria, the other children of the family must remain away from school although

they are perfectly well. This is a real hardship to the sick family, but if the children went to school they would carry germs with them, and would spread the disease to their companions. Better one sick family than a dozen.

In order to prevent the spread of disease the Board of Health not only quarantines the house during the illness but it also disinfects the house after the illness. Such rigid laws by the Board of Health are necessary to prevent disease epidemics.

Contagious diseases are not all reported to the Board of Health and quarantined; tuberculosis, for example, which is one of our common diseases, is not reported and quarantined. Usually the quarantined diseases are those which cause sudden and severe illness and can be promptly cured by medical attention. Recovery from consumption is slow, but multitudes of people suffer from this disease, and it would be impossible to isolate all consumptives for the entire period of their illness. Then, too, one of the cures for consumption is out-door air, and the person must be sent into the streets during the illness.

CHAPTER XXII

SIMPLE ELECTRIC DEVICES

MANY animals possess the power to see, to hear, to smell, to taste, and to feel, but only man is able to build on the information gained through these senses. It is his constructive power that raises man above the level of the beasts and enables him to devise and fashion wonderful inventions. Among the most important of his inventions are those which relate to electricity, — inventions such as trolley cars, elevators, automobiles, electric lights, the telephone, the telegraph. Alexander Bell, by his superior constructive ability, made possible the practical use of the telephone, and Marconi, the wireless telegraph. To these inventions might be added many others which have increased the efficiency and production of the business world and have decreased the labor and strain of domestic life.

Electricity as first obtained by man. — Until modern times the only electricity known was that of lightning and that produced by rubbing amber with fur or wool. But in the year 1800, electricity in the form of a weak current was obtained by Volta of Italy in a very simple way. Even now our various electric batteries and cells are but a modification of the voltaic cell used by Volta. A strip of copper and one of zinc are placed in a glass of sulphuric acid dissolved in water. Sulphuric acid is composed of oxygen, hydrogen, and sulphur. As soon as the plates

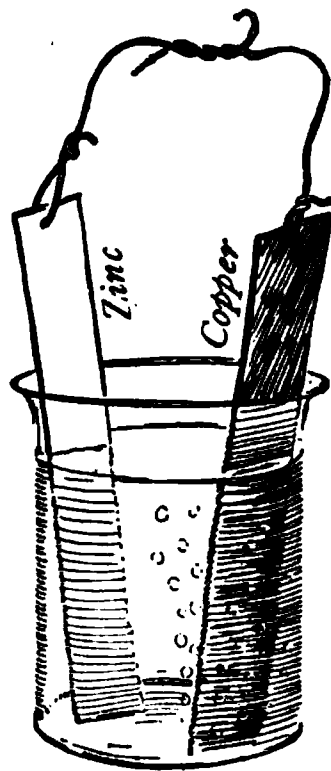


FIG. 73. — A simple electric cell.

are immersed in the acid, minute bubbles of gas rise from the zinc strip and it begins to waste away slowly. The solution gradually dissolves the zinc and at the same time gives up some of the hydrogen which it contains; but it has little or no effect on the copper, since there is no visible change in the copper strip.

If, now, the strips are connected by means of metal wires, the zinc wastes away rapidly, numerous bubbles of hydrogen pass over to the copper strip and collect on it, and a current of electricity flows through the connecting wires. Evidently, the source of the current is the chemical action between the zinc and the liquid.

Mere inspection of the connecting wire will not enable us to determine that a current is flowing, but there are various ways in which the current makes itself evident. If the ends of the wires attached to the strips are brought in contact with each other and then separated, a faint spark passes, and if the ends are placed on the tongue, a twinge is felt.

Experiments which grew out of the voltaic cell. — Since chemical action on the zinc is the source of the current, it would seem reasonable to expect a current if the cell consisted of two zinc plates instead of one zinc plate and one copper plate. But when the copper strip is replaced by a zinc strip so that the cell consists of two similar plates, no current flows between them. In this case, chemical action is expended in heat rather than in the production of electricity and the liquid becomes hot. But if carbon and zinc are used, a current is again produced, the zinc dissolving away as before and bubbles collecting on the carbon plate. By experiment it has been found that many different metals may be employed in the construction of an electric cell; for example, current may be obtained from a cell made with a zinc plate and a platinum plate, or from a cell made with a lead plate and a copper plate. Then, too, some other chemi-

cal, such as bichromate of potassium, or ammonium chloride, may be used instead of dilute sulphuric acid.

There are many different substances that will, under proper conditions, give a current, but the strength of the current is in some cases so weak as to be worthless for practical use, such as telephoning, or ringing a doorbell. What is wanted is a strong, steady current, and our choice of materials is limited to the substances which give this result. Zinc and lead can be used, but the current resulting is weak and feeble; for general use zinc and carbon are the most satisfactory.

Electrical terms. - The plates or strips used in making an electric cell are called electrodes; the zinc is called the negative electrode (-), and the carbon the positive electrode (+); the current is considered to flow through the wire from the positive to the negative electrode. As a rule, each electrode has a binding post to which wires can be quickly fastened.

The force that causes the current is called voltage or electromotive force; the value of the voltage depends upon the materials used in the cell. When the cell consists of copper, zinc, and dilute sulphuric acid, the voltage has a definite value which is always the same no matter what the size or shape of the cell. But the voltage has a decidedly different value in a cell composed of iron, copper, and chromic acid. We need a unit of voltage and of current just as we need units of time, length, and weight. The unit of voltage is called the volt. The unit of current is called the ampere.

Dry cells. - The simple voltaic cell is not convenient for general use. The *dry cell* is the most popular modern cell because of the ease with

FIG. 74. - A dry cell.

which it can be taken from place to place. This cell (Fig. 74) consists of a zinc cup, within which is a carbon rod; the space between the cup and rod is packed with a moist paste containing certain chemicals. The moist paste takes the place of the liquids used in other cells.

A battery of cells. — The electromotive force of one cell may not give a current strong enough to ring a doorbell or to operate a telephone. But by using a number of cells, called a battery, the current may be increased to almost any desired strength. If three cells are arranged as in Figure 75, so that

the copper of one cell is connected with the zinc of another cell, the voltage of the battery will be three times as great as the voltage of a single cell. If four cells are arranged in the same way, the voltage of the battery is four times as

FIG. 75. — A battery of three cells.

great as the voltage of a single cell; when five cells are combined, the voltage is five times as great.

Heat. Any one who handles electric wires knows that they are more or less heated by the currents which flow through them. If three cells are arranged as in Figure 75 and the connecting wire is coarse, the heating of the wire is scarcely noticeable; but if a shorter wire of the same kind is used, the heat produced is slightly greater; and if the coarse wire is replaced by a short, fine wire, the heating of the wire becomes very marked. We are accustomed to say that a wire offers resistance to the flow of a current; that is, whenever a current meets resistance, heat is produced in much the same way as when mechanical motion meets an obstacle and spends its energy in friction. The flow of electricity along a wire can be compared to the flow of water through pipes: a small pipe offers a greater

resistance to the flow of water than a large pipe; less water can be forced through a small pipe than through a large pipe, but the friction of the water against the sides of the small pipe is much greater than in the large one.

So it is with the electric current. In fine wires the resistance to the current is large and the energy of the battery is expended in heat rather than in current. If the heat thus produced is very great, serious consequences may arise; for example, the contact of a hot wire with wall paper or dry beams may cause fire. Insurance companies demand that the wires used in wiring a building for electric lights be of a size suitable to the current to be carried, otherwise they will not take the risk of insurance. The greater the current to be carried, the coarser is the wire required for safety.

Electric devices for the home.— It is often desirable to utilize the electric current for the production of heat. For example, trolley cars are heated by coils of wire under the seats. The coils offer so much resistance to the passage of a strong current through them that they become heated and warm the cars.

Some modern houses are so built that electricity is received into them from the great plants where it is generated, and by merely turning a switch or inserting a plug, electricity is constantly available. In consequence, many practical applications of electricity are possible, among which are flatiron and toaster.

Within the flatiron (Fig. 76) is a mass of fine wire coiled as shown in Figure 77. As soon as the iron is connected with the house supply of electricity, current flows through the fine wire, which becomes strongly heated and gives off heat to the iron. The iron, when once heated, retains an even temperature

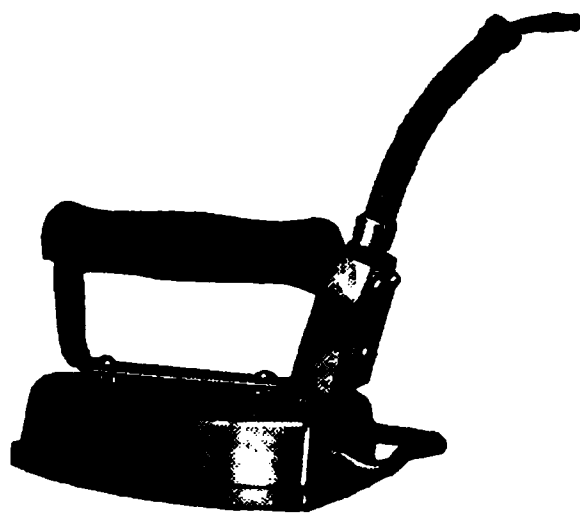


FIG. 76. — An electric iron.

as long as the current flows, and the laundress is free from the disadvantages of a slowly cooling iron, and is relieved



FIG. 77 The fine wires are strongly heated by the current which flows through them

of frequent substitution of a warm iron for a cold one. Electric irons are particularly valuable in summer, because they eliminate the necessity for a strong fire, and spare the housewife intense heat. In addition, the user is not confined to the laundry, but is free to

seek the coolest part of the house, the only requisite being an electrical connection.

The toaster (Fig. 78) is another useful electric device, since by means of it toast may be made on a dining table or

A

FIG. 78. — Electric devices: A. An electric toaster; B. An electric stove.

at a bedside. The small electric stove, shown in Figure 78, is similar in principle to the flatiron. In it the heating coil is

FIG. 79. — Base of an electric heater cut away to show the resistance wire which is heated by the electric current.

FIG. 80. — An electric pad serves the same purpose as a hot-water bag.

arranged as shown in Figure 79. To the physician electric stoves are valuable, since his instruments can be sterilized in water heated by the stove, and without coal or odor of gas.

A convenient device is seen in the heating pad (Fig. 80), a substitute for a hot-water bag. Embedded in some soft thick substance are insulated wires in which heat is developed, and over this is placed a covering of felt.

Electric lights. — The incandescent bulbs which illuminate our buildings consist of a fine, hairlike thread inclosed in a glass bulb from which the air has been removed (Fig. 81). When an electric current is sent through the delicate filament, it meets a strong resistance. The heat developed in overcoming the resistance is so great that it makes the filament a glowing mass. The absence of air prevents the filament from burning, and it merely glows and radiates the light.

Resistance. — Since resistance plays so important a rôle in electricity, it becomes necessary to have a unit of resistance. The practical unit of resistance is called an ohm, and some idea of the value of an ohm can be obtained if we remember that a 300-foot length of common iron telegraph wire has a resistance of 1 ohm.

FIG. 81. — An incandescent electric bulb.

An approximate ohm for rough work may be made by winding 9 feet 5 inches of number 30 copper wire¹ on a spool or arranging it in any other convenient form.

Substances differ very greatly in the resistance which they offer to electricity. It takes 300 feet of iron telegraph wire to give 1 ohm of resistance; 39 feet of number 24 copper wire, and but 2.2 feet of number 24 German silver wire.

¹ The number of a wire indicates its diameter; number 30, for example, being always of a definite fixed diameter, no matter what the material of the wire.

If we wish to avoid loss of current by heating, we use a wire that offers little resistance. If we wish to transform electricity into heat, as in the electric stove, we choose wire of high resistance, as German silver wire.

Chemical effects. *The plating of gold, silver, and other metals.* — If strips of lead or rods of carbon are connected to the terminals of an electric cell, as in Figure 82, and are then dipped into a solution of copper sulphate, the strip in connection with the negative terminal of the cell soon becomes thinly plated with a coating of copper. If a solution of silver nitrate

is used in place of the copper sulphate, the coating is of silver instead of copper. As long as the current flows and there is any metal present in the solution, the coating continues to form on the negative electrode, and becomes thicker and thicker.

FIG. 82. — Carbon rods in a solution of copper sulphate.

The process by which metal is taken out of solution, as silver out of silver nitrate and copper out of copper sulphate, and is in turn deposited as a coating on another substance, is called **electroplating**. An electric current separates a liquid into some of its various constituents and deposits one of the metal constituents on the negative electrode.

Since copper is constantly taken out of the solution of copper sulphate for deposit upon the negative electrode, the amount of copper remaining in the solution steadily decreases, and finally there is none of it left for deposit. In order to overcome this, the positive electrode is made of the same metal as that which is to be deposited. The positive metal electrode gradually dissolves and replaces the metal lost from the solution by deposit, and electroplating can continue as long as any positive electrode remains.

Practically all silver, gold, and nickel plating is done in this way; machine, bicycle, and motor attachments are not solid nickel, but are of cheaper material electrically nickelplated. When spoons are to be plated, they are hung in a solution of silver salts side by side with a thick slab of pure silver, as in Figure 83. The spoons are connected with the negative terminal of the battery, while the slab of pure silver is connected with the positive terminal. The length of time that the current flows determines the thickness of the plating.

How pure metal is obtained from ore. — When ore is mined, it contains in addition to the desired metal many other substances. In order to separate out the desired metal, the ore is placed in some suitable acid bath, and is connected with the positive terminal of a battery, thus taking the place of the silver slab in the last section. When current flows, any pure metal which is present is dissolved out of the ore



FIG. 83. — Plating spoons by electricity.

and is deposited on a convenient negative electrode, while the impurities remain in the ore or drop as sediment to the bottom of the vessel. Metals separated from the ore by electricity are called electrolytic metals and are the purest obtainable.

Printing. — The ability of the electric current to decompose a liquid and to deposit a metal constituent has practically revolutionized the process of printing. Formerly, type was arranged and retained in position until the required number of impressions had been made, the type meanwhile being unavailable for other uses. Moreover, the printing of a second edition necessitated practically as great labor as did the printing of the

first edition, the type being necessarily set afresh. Now, however, the type is set up and a mold of it is taken in wax. This mold is coated with graphite to make it a conductor and is then suspended in a bath of copper sulphate, side by side with a slab of pure copper. Current is sent through the solution, until a thin coating of copper has been deposited on the mold. The mold is then taken from the bath, and the wax is replaced by some metal which gives strength and support to the thin copper plate. From this copper plate, which is an exact reproduction of the original type, many thousand copies can be printed. The plate can be preserved and used for later editions.

CHAPTER XXIII

MODERN ELECTRICAL INVENTIONS

An electric current acts like a magnet. — In order to understand the action of the electric bell, we must consider a third effect which an electric current can cause. Connect some cells as shown in Figure 75 and close the circuit through a stout heavy copper wire, dipping a portion of the wire into fine iron filings. A thick cluster of filings adheres to the wire (Fig. 84), and continues to cling to it as long as the current flows. If the current is broken, the filings fall from the wire, and only as long as the current flows through the wire does the wire have power to attract iron filings. An electric current makes a wire equivalent to a magnet, giving it the power to attract iron filings.

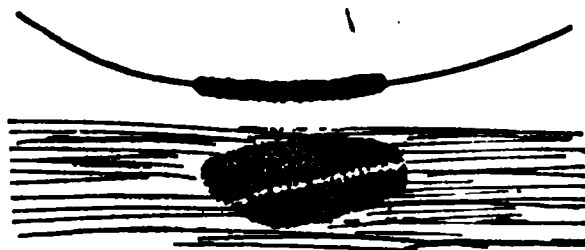


FIG. 84. — A wire carrying current attracts iron filings.

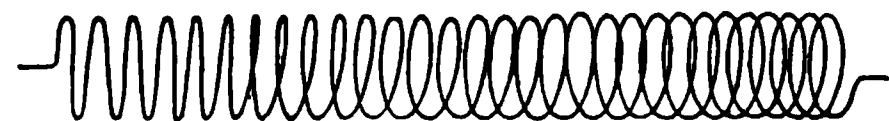


FIG. 85. — A loosely wound coil of wire.

strength can be increased by coiling as in Figure 85. Such an arrangement of wire is known

as a helix or solenoid, and is capable of lifting or pulling larger and more numerous filings and even good-sized pieces of iron, such as tacks. Filings do not adhere to the sides of the helix, but they cling in clusters to the ends of the coil. This shows that the ends of the helix have magnetic power but that the sides have not.



FIG. 86. —
Coil and
soft iron
rod.

If a soft iron nail (Fig. 86) or its equivalent is slipped within the coil, the lifting and attractive power of the coil is increased, and comparatively heavy weights can be lifted.

A coil of wire traversed by an electric current and containing a core of soft iron has the power of attracting and moving heavy iron objects; that is, it acts like a magnet. Such an arrangement is called an electromagnet. As soon as the current ceases to flow, the electromagnet loses its magnetic power and becomes merely iron and wire without magnetic attraction.

If many cells are used, the strength of the electromagnet is increased, and if the coil is wound closely, as in Figure 87, instead of loosely, as in Figure 85, the magnetic strength is still further increased. The strength of any electromagnet depends upon the number of coils wound on the iron core and upon the strength of the current which is sent through the coils.

To increase the strength of the electromagnet still further, the so-called horse-shoe shape is used (Fig. 88). In such an arrangement there is practically the strength of two separate electromagnets.

FIG. 87. — An
electromagnet.

FIG. 88. — A horseshoe
electromagnet strong
enough to support heavy
weights in a pan.

The electric bell. — The ringing of an electric bell is due to the attractive power of an electromagnet. By pushing a button (Fig. 89, *B*) connection is made with a battery, and current flows through the wire wound on the iron spools, and further to the screw *P* which presses against the

soft iron strip or armature *S*; and from *S* the current flows back to the battery. As soon as the current flows, the coils become magnetic and attract the soft iron armature, drawing it forward and causing the clapper to strike the bell. In this position, *S* no longer touches the screw *P*, and hence there is no complete path for the electricity, and the current ceases. But the attractive,

R

magnetic power of the coils stops as soon as the current ceases; hence there is nothing to hold the armature down, and it flies back to its former position. In doing this, however, the armature makes contact with the spring, and the current flows again. As a result the coils again become magnetic, the armature is again drawn forward, and the clapper again strikes the bell. Immediately afterwards the armature springs backward and makes contact with the other spring, and the entire operation is repeated. When you press the button, this process is repeated, producing what sounds like a continuous ringing; in reality the clapper strikes the bell a number of times a current passes through

FIG. 89. — The electric bell.

The push button. — The push button is an essential to the operation of every electric bell, because without it the bell either would not ring at all, or would ring incessantly until the cell was exhausted. When the push button is free, as in Figure 90, the cell terminals are not connected in an unbroken path, and hence the current does not flow. When, however, the button is pressed, the current has a complete path, provided there is the proper connection at

P (Fig. 89). That is, the pressure on the push button permits current to flow to the bell. The flow of this current depends solely upon the connection at P , which is alternately made and broken, and in this way produces sound.

The sign "Bell out of order" is usually due to the fact that the battery is either temporarily or permanently exhausted. If wet cells are used, the liquid may dry up in warm weather and stop the current or the liquid may have eaten up all the



FIG. 90. — Push button.

zinc. These difficulties may be remedied by adding water or by renewing the zinc. If dry cells are used, there is no remedy except in the purchase of new cells.

How electricity may be lost to use. — In the electric bell, we saw that an air gap at the push button stopped the flow of electricity. If we cut the wire connecting the poles of a battery, the current ceases because an air gap intervenes and electricity does not readily pass through air. Many substances besides air stop the flow of electricity. If a strip of glass, rubber, mica, or paraffin is introduced anywhere in a circuit, the current ceases. If a metal is inserted in the gap, the current again flows. Substances which, like an air gap, interfere with the flow of electricity are called non-conductors, or, more commonly, insulators. Substances which, like the earth, the human body, and all other moist objects, conduct electricity are conductors. If the telephone and electric light wires in our houses were not insulated by a covering of thread or cloth, or other non-conducting material, the electricity would escape into surrounding objects, instead of flowing through the wire and producing sound and light.

In our city streets, the overhead wires are supported on glass knobs or are closely wrapped with a non-conducting material, in order to prevent the escape of electricity through

the poles to the ground. In order to have a steady, dependable current, the wire carrying the current must be insulated.

Lack of insulation means not only the loss of current for practical uses, but also serious consequences in the event of the crossing of current-bearing wires. If two wires properly insulated touch each other, the currents flow along their respective wires unaltered; if, however, two uninsulated wires touch, some of the electricity flows from one to the other. Heat is developed as a result of this transference, and the heat thus developed is sometimes so great that fire occurs. For this reason, wires are heavily insulated and extra protection is provided at points where numerous wires touch or cross.

Conductors and insulators are necessary to the efficient and economic flow of a current, the insulator preventing the escape of electricity and lessening the danger of fire, and the conductor carrying the current.

The telegraph. — Telegraphy is the process of transmitting messages from place to place by means of an electric current. The principle underlying the action of the telegraph is the principle upon which the electric bell operates; namely, that a piece of soft iron becomes a magnet while a current flows around it, but loses its magnetism as soon as the current ceases to flow around it.

In the electric bell, the electromagnet, clapper, push button, and battery are relatively near, — usually all are located in the same building. In the telegraph the current may travel miles before it reaches the electromagnet and produces motion of the armature.

The fundamental connections of the early telegraph are shown in Figure 91. If the key *K* is pressed down by an operator in Philadelphia, the current from the battery (only one cell is shown for simplicity) flows through the line to New York, passes through the electromagnet *M*, and then back to Phila-

delphia. As long as the key *K* is pressed down, the coil *M* acts as a magnet and attracts and holds fast the armature *A*. But as soon as *K* is released, the current is broken, *M* loses its magnetism, and the armature is pulled back by the spring *D*. By a mechanical device, tape is drawn uniformly under the light marker *P* attached to the armature. If *K* is closed for but a short time, the armature is drawn down for but a short interval, and the marker registers a dot on the tape *T*.

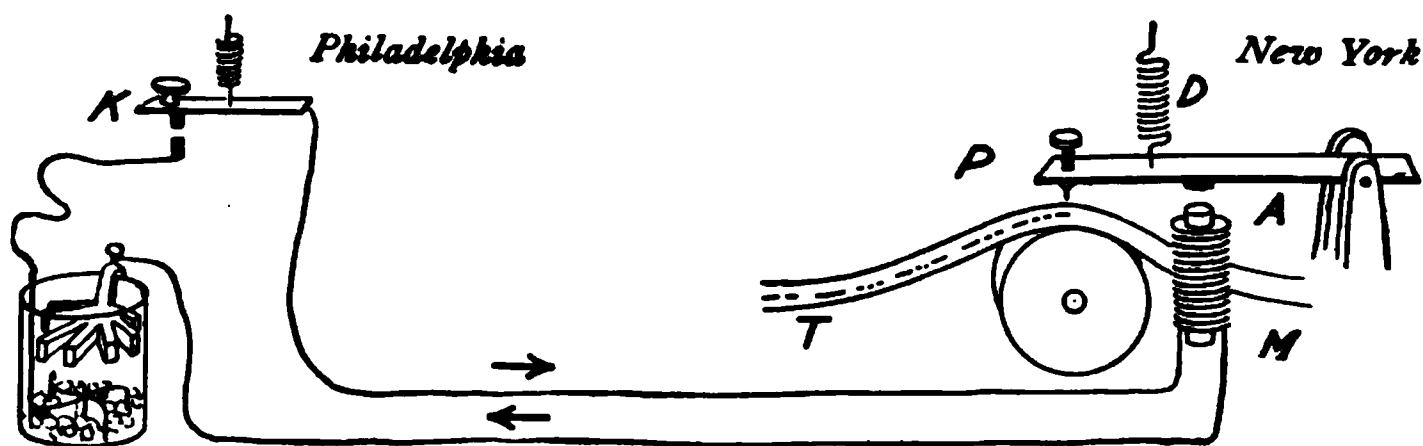


FIG. 91. — Diagram of the electric telegraph.

If *K* is closed for a longer time, a short dash is made by the marker. In general, the length of time that *K* is closed determines the length of the marks recorded on the tape. The telegraphic alphabet consists of dots and dashes and their various combinations, and hence an interpretation of the dot and dash symbols recorded on the tape is all that is necessary for the receiving of a telegraphic message.

The Morse telegraphic code, consisting of dots, dashes, and spaces, is given in Figure 92.

A. _	H.	O. . .	U. _ _
B. _ . . .	I. . .	P.	V. . . _
C. . . .	J. _ . . .	Q. _ . . .	W. _ _ _
D. _ . .	K. _ _ _	R. . . .	X. _ . . .
E. .	L. _ _ _	S. . . .	Y.
F. _ . .	M. _ _ _	T. _ _ _	Z.
G. _ . .	N. _ . .		

FIG. 92. — The Morse telegraphic code.

The telegraph is now such a universal means of communication between distant points that one wonders how business was conducted before its invention in 1832 by S. F. B. Morse.

Shortly after the invention of telegraphy, operators learned that they could read the message by the click of the marker against a metal rod which took the place of the tape. In all telegraph offices of the present day the old-fashioned tape is replaced by the sounder, shown in Figure 93. When current flows, a lever, *L*, is drawn down by the electromagnet and strikes

against a solid metal piece with a click; when the current is broken, the lever springs upward, strikes another metal piece and makes a different click. It is clear that the working of the key which starts and stops the current in this line will be

FIG. 93. — The sounder.

imitated by the clicks of the sounder. By means of these varying clicks of the sounder, the operator interprets the message.

The earth an important part of a telegraphic system. — In the early telegraph lines, two wires were used, as in Figure 91; then it was found that a railroad track could be substituted for one wire, and later that the earth itself served equally well for a return wire. In the present arrangement there is but one wire, the circuit being completed by the earth. No fact in electricity seems more marvelous than that the thousands of messages flashing along the wires overhead are likewise traveling through the ground beneath. If it were not for this use of the earth as an unfailing conductor, the network of overhead wires in our city streets would be even more complex than it now is.

Advances in telegraphy.—The mechanical improvements in telegraphy have been so rapid that at present a single operator can easily send or receive forty words a minute. He can telegraph more quickly than the average person can write; and with a combination of the latest improvements the speed can be enormously increased.

In actual practice messages are not ordinarily sent long distances over a direct line, but are automatically transferred to new lines at definite points. For example, a message from New York to Chicago does not travel along an uninterrupted path, but is automatically transferred at some point, such as Lancaster, to a second line which carries it on to Pittsburgh, where it is again transferred to a third line which takes it farther on to its destination. The modern telegraph is much more complex than the early form owing to the numerous devices which have been added to increase its efficiency.

CHAPTER XXIV

MAGNETS AND CURRENTS

IN the twelfth century, there was introduced into Europe from China a simple instrument which changed journeying on the sea from uncertain wandering to a definite, safe voyage. This instrument was the compass (Fig. 94), and because of the property of the compass needle (a magnet) to point unerringly north and south, sailors were able to determine directions on the sea and to steer for the desired point.

Since an electric current is practically equivalent to a magnet, it becomes necessary to know the most important facts relative to magnets, facts simple in themselves but of far-reaching value and consequences in electricity. Without a knowledge of the magnetic characteristics of cur-

rents, the construction of the motor would have been impossible, and trolley cars, electric fans, motor boats, and other equally well-known electrical contrivances would be unknown.

The attractive power of a magnet. — The magnet best known to us all is the compass needle, but for convenience we use a magnetic needle in the shape of a bar larger and stronger than that employed in the compass. If we lay such a magnet on a pile of iron carpet tacks, we find on lifting the magnet that the tacks cling to the ends in abundance, but leave it almost

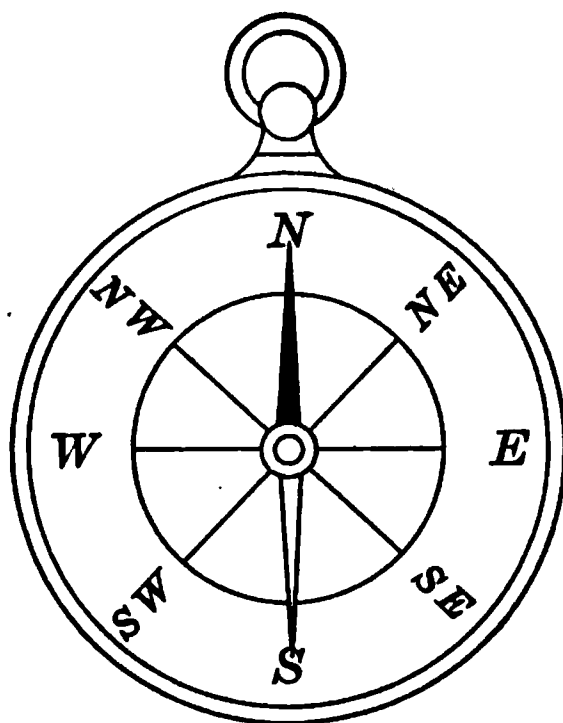


FIG. 94. — The compass.

bare in the center (Fig. 95). The points of attraction at the two ends are called the poles of the magnet.



FIG. 95. — A magnet.

If a delicately made magnet is suspended as in Figure 96, and is allowed to swing freely, it always assumes a definite north-and-south position. The pole which points north when the needle is suspended is called the north pole and is marked

N, while the pole which points south when the needle is suspended is called the south pole and is marked *S*.

A freely suspended magnet points nearly north and south. A magnet has two main points of attraction called respectively the north and the south pole.

The extent of magnetic attraction. — If a thin sheet of paper or cardboard is laid over a strong, bar-shaped magnet and iron filings are then gently strewn on the paper, the filings clearly indicate the position of the magnet beneath, and if the cardboard is gently tapped, the filings arrange themselves as shown in Figure 97. If the paper is held some distance above the magnet, the influence on the filings is less definite, and finally, if the paper is held far away, the filings do not respond at all, but lie on the cardboard as dropped.

The magnetic power of a magnet, while not confined to the magnet itself, does not extend indefinitely into the surrounding region; the influence is strong near the magnet, but at a distance becomes so weak as to be inappreciable. The region around a magnet through which its magnetic force is felt is called the field of force, or simply the magnetic



FIG. 96. — The magnetic needle.

FIG. 97. — Iron filings scattered over a magnet arrange themselves in definite lines.

field, and the definite lines in which the filings arrange themselves are called lines of force.

The influence of magnets upon each other. — If a magnet is brought near a magnetic needle, the needle turns; that is, motion is produced (Fig. 98). If the north pole of the free magnet is brought toward the south pole of the suspended magnet, the latter moves in such a way that the two poles *N* and *S* are as close together as possible. If the north pole of the free magnet is brought toward the north pole of the suspended magnet, the latter moves in such a way that the two poles *N* and *N* are as far apart as possible. In every case that can be tested, it is found that a north pole repels a north pole, and a south pole repels a south pole; but that a north and a south pole always attract each other.

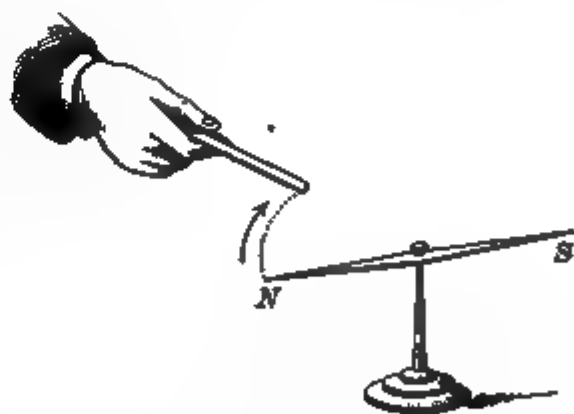


FIG. 98. — A south pole attracts a north pole.

The main facts about magnets may be summed up thus: —

a. A magnet points nearly north and south if it is allowed to swing freely.

b. A magnet contains two unlike poles, one of which persistently points north, and the other of which as persistently points south, if allowed to swing freely.

c. Poles that are alike repel each other; poles that are unlike attract each other.

d. A magnet possesses the power of attracting certain substances, like iron, and this power of attraction is not limited to the magnet itself but extends into the region around the magnet.

Magnetic properties of an electric current. — If a current-bearing wire is really equivalent in its magnetic powers to a

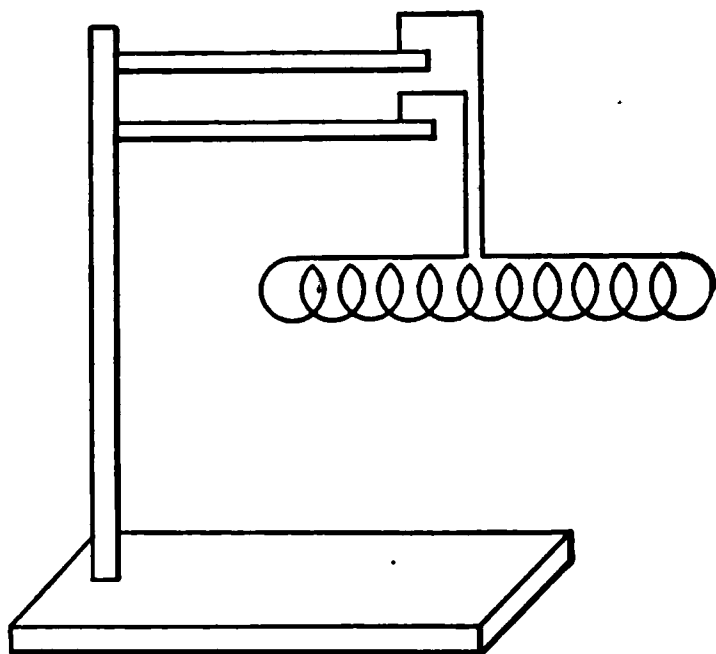


FIG. 99. — A helix through which current flows always points north and south, if it is free to rotate.

magnet, it must possess all of the characteristics mentioned in the preceding section. That a coil through which current flows possesses the characteristics *a*, *b*, *c*, and *d* of a magnet is shown as follows: —

a, b. When a helix marked at one end with a red string is arranged so that it is free to rotate and a strong current is sent through it, the helix immediately turns and faces about

until it points north and south. If it is disturbed from this position, it swings slowly back and forth until it occupies its characteristic north-and-south position. The end to which the string is attached persistently points either north or south. If the current is sent through the coil in the opposite direction, the two poles exchange positions and the helix turns until the new north pole points north.

c. If a helix is held near a suspended magnet, one end of the helix attracts the north pole of the magnet, while the opposite end repels the north pole of the magnet. In fact, the helix behaves in every way as a magnet, with a north pole at one end and a south pole at the other. If the current is sent through the helix in the opposite direction, the north and south poles exchange places.

If the number of turns in the helix is reduced until but a single loop remains, the result is the same; the single loop acts like a flat magnet, one side of the loop always facing north and one south, and one face attracting the north pole of the suspended magnet and one repelling it.

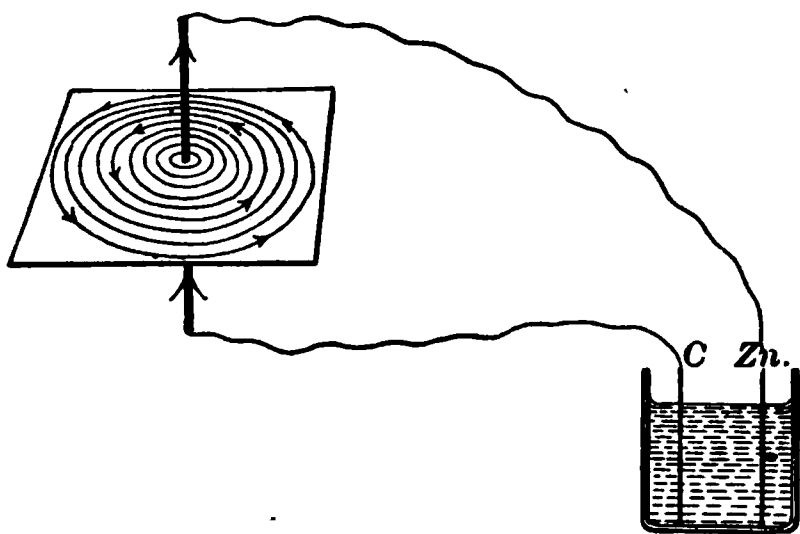


FIG. 100. — A wire through which current flows is surrounded by a field of magnetic force.

d. If a wire is passed through a card and a strong current is sent through the wire, iron filings will, when sprinkled upon the card, arrange themselves in definite directions (Fig. 100). A wire carrying a current is surrounded by a magnetic field of force.

A magnetic needle held under a current-bearing wire turns on its pivot and finally comes to rest at an angle with the current. The fact that the needle is deflected by the wire shows that the magnetic power of the wire extends into the surrounding medium.

The magnetic properties of current electricity were discovered by Oersted of Denmark less than a hundred years ago; but since that time practically all important electrical machinery has been based upon one or more of the magnetic properties of electricity. The motors which drive our electric

fans, our mills, and our trolley cars owe their existence entirely to the magnetic action of current electricity.

The principle of the motor. — When a coil of wire is suspended between the poles of a strong horseshoe magnet, it does not assume any characteristic position but remains where-

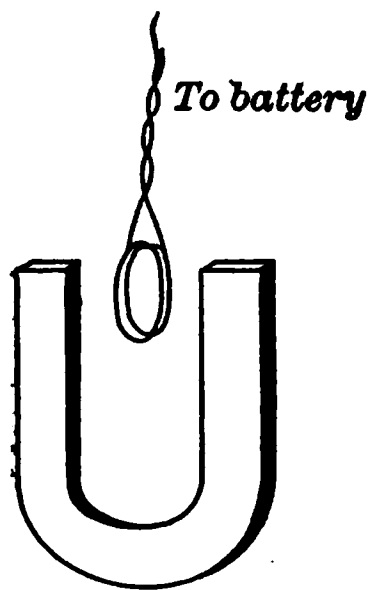


FIG. 101. — The coil turns in such a way that its north pole is opposite the south pole of the magnet.

ever placed. If, however, a current is sent through the wire, the coil faces about and assumes a definite position. This is because a coil, carrying a current, is equivalent to a magnet with a north and a south face; and, in accordance with the magnetic laws, tends to move until its north face is opposite the south pole of the horseshoe magnet, and its south face is opposite the north pole of the magnet.

If, when the coil is at rest in this position, the current is reversed, so that the north pole of the coil becomes a south pole and the former south pole becomes a north pole, the result is that like poles of coil and magnet face each other. But since like poles repel each other, the coil moves, and rotates until its new north pole is opposite the south pole of the magnet and its new south pole is opposite the north pole. By sending a strong current through the coil, the helix is made to rotate through a half turn; by reversing the current when the coil is at the half turn, the helix is made to continue its rotation and to swing through a whole turn. If the current is repeatedly reversed just as the helix completes its half turn, the motion is continuous. Periodic current reversal produces continuous rotation. This is the principle of the motor.

It is easy to see that long-continued rotation would be impossible in the arrangement of Figure 101, since the twisting of the suspending wire would interfere with free motion. In

an actual motor¹ a device is employed by means of which the helix is capable of continued rotation around its support.

The rotating coil is usually spoken of as the armature, and the large magnet as the field magnet.

If a wheel is attached to the rotating coil, weights can be lifted, and if a belt is attached to the wheel, the motion of the rotating helix can be transferred to machinery for practical use. The motion of the blades of an electric fan which gives us comfort on hot summer days is derived from the rotary motion of the motor (Fig. 102).

Trolley cars. — A motor constructed with only a single coil of wire in its armature, rotates too slowly and with too little force for practical use. If a motor is to be of real service, its armature must rotate with sufficient strength to impart motion to the wheels of trolley

FIG. 102. — An electric fan.

FIG. 103. — A modern electric power plant.

¹ In the actual motor, the reversal of the current is secured by a simple mechanical device, called a commutator.

cars and mills, to drive electric fans, and to set in motion many other forms of machinery.

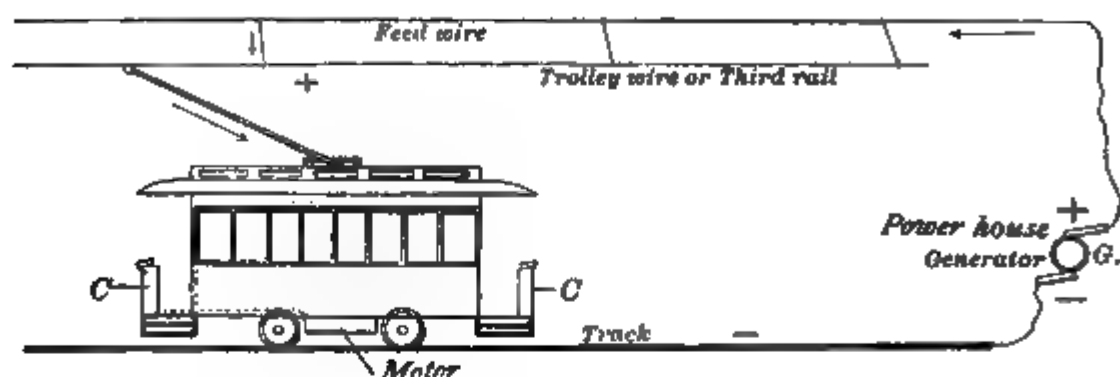


FIG. 104. — The electric street car.

The strength of a motor is increased by replacing the singly coiled armature by one closely wound on an iron core; in some armatures there are thousands of turns of wire. The presence

of soft iron within the armature causes greater attraction between the armature and the outside magnet, and hence greater force of motion. The magnetic strength of the field magnet influences greatly the speed of the armature; the stronger the field magnet the greater the motion, so electricians make every effort to strengthen their field magnets.

FIG. 105 - A motor runs the sewing machine.

When very powerful motors are necessary, the field magnet is so arranged that it has four or more poles instead of two; and the armature consists of several portions. But no

matter how complex these various parts may seem to be, the principle is the same in all of them, and the parts are limited to field magnet, commutator, and armature.

Nearly all electric street cars (Fig. 104) are set in motion by powerful motors placed under the cars. As the armature rotates, its motion is communicated by gears to the wheels, the necessary current reaching the motor through the overhead wires.

Small motors may be used to great advantage in the home, where they serve to turn the wheels of sewing machines, and to operate washing machines. Vacuum cleaners are frequently run by motors.

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CHAPTER XXV

HOW ELECTRICITY IS OBTAINED ON A LARGE SCALE

One source. — We have learned that cells furnish current as a result of chemical action, and that the substance usually consumed within the cell is zinc. Just as coal by combustion furnishes heat, so zinc within the cell furnishes electricity. But zinc is a much more expensive fuel than coal or oil or gas, and to run a large motor by electricity produced in this way would be very much more expensive than to run the motor by water or steam. For weak and infrequent currents such as are used in the electric bell, only small quantities of zinc are needed and the expense is small. But for the production of such powerful currents as are needed to drive trolley cars, elevators, and huge machinery, enormous quantities of zinc would be necessary and the cost would be prohibitive. It is safe to say that electricity would never have been used on a large scale if some less expensive and more convenient source than zinc had not been found.

A new source of electricity. — It came to most of us as a surprise that an electric current has magnetic properties and transforms a coil into a veritable magnet. Perhaps it will not surprise us now to learn that a magnet in motion has electric properties, and is able to produce a current within a wire. This can be proved as follows: —

Attach a closely wound coil to a current detector or galvanometer (Fig. 106); naturally there is no deflection of the galvanometer needle, because there is no current in the wire. Now

thrust a magnet into the coil. Immediately there is a deflection of the needle, which indicates that a current is flowing through the circuit. If the magnet remains at rest within the coil, the needle returns to its original position, showing that the current has ceased. Now let the magnet be withdrawn from the coil; the needle is deflected as before, but the deflec-

FIG. 106. — The motion of a magnet within a coil of wire produces a current of electricity.

tion is in the opposite direction, showing that a current exists, but that it flows in the opposite direction. We learn, therefore that a current may be induced in a coil by moving a magnet back and forth within the coil, but that a magnet at rest within the coil has no such influence.

A magnet possesses lines of force, and as the magnet moves toward the coil, it carries lines of force with it. As the magnet recedes from the coil, it carries lines of force away with it.

The dynamo.—Between the poles of a strong magnet suspend a movable coil which is connected with a sensitive galvanometer (Fig. 107). Starting with the coil in the position of Figure 101, when many lines of force pass through it, let the coil be rotated quickly until it reaches the position indicated in Figure 107, when no lines of force pass through it. During the motion of

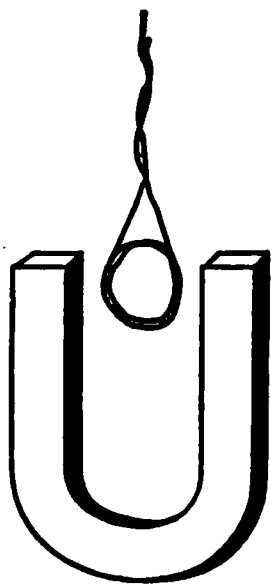


FIG. 107. — As long as the coil rotates between the poles of the magnet, current flows.

the coil, a strong deflection of the galvanometer is observed; but the deflection ceases as soon as the coil ceases to rotate. If, now, starting with the position of Figure 107, the coil is rotated forward to its starting point, a deflection occurs in the opposite direction, showing that a current is present, but that it flows in the opposite direction. As long as the coil is in motion, current is induced in the coil.

The above arrangement is a dynamo in miniature.

By rotation of a coil (armature) within a magnetic field, that is, between the poles of a magnet, current is obtained.

In the *motor*, current produces motion. In the *dynamo*, motion produces current.

Every dynamo, no matter how complex its structure and appearance, consists of a coil of wire which can rotate continuously between the poles of a strong magnet.

The current obtained from such a dynamo alternates in direction, flowing first in one direction and then in the opposite direction. Such alternating currents are unsatisfactory for many purposes, and to be of service are in many cases transformed into direct currents; that is, currents which flow steadily in one direction. This is accomplished by the use of a commutator.

A small dynamo, such as is used for lighting fifty incandescent lamps, has a horse power of about 3 to 4, and large dynamos are frequently as powerful as 7500 horse power.

The telephone. — When a magnet is at rest within a closed coil of wire (Fig. 106), current does not flow through the wire. But if a piece of iron is brought near the magnet, current is induced and flows through the wire; if the iron is withdrawn, current is again induced in the wire but flows in the opposite

FIG. 108. — A modern electric machine.

direction. As iron approaches and recedes from the magnet, current is induced in the wire surrounding the magnet. This is in brief the principle of the telephone. When one talks into a receiver, *L* (Fig. 110), the voice throws into vibration a sensitive iron plate standing before an electromagnet. The back-and-forth motion of the iron plate induces current in the electromagnet *c*. The current thus induced makes itself evident at the opposite end of the line *M*, where by its magnetic attraction, it throws a second iron plate into vibration. The vibrations of the second plate are similar to those produced in

the first plate by the voice. The vibrations of the far plate thus reproduce the sounds uttered at the opposite end.

FIG. 109. — Thomas Edison, one of the foremost electrical inventors of the present day.

Cost of electric power. — The water power of a stream depends upon the quantity of water and the force with which it flows. The electric power of a current depends upon the

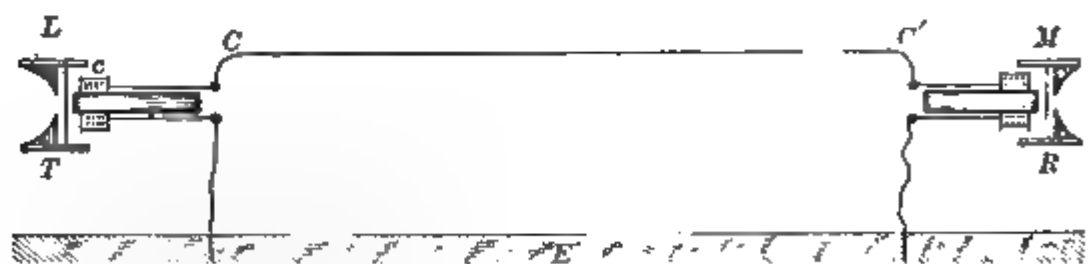


FIG. 110. — Diagram of a simple telephone circuit.

quantity of electricity and the force under which it flows. The unit of electric power is called the watt; it is the

power furnished by a current of one ampere with a voltage of one volt.

One watt represents a very small amount of electric power, and for practical purposes a unit 1000 times as large is used, namely, the kilowatt. By experiment it has been found that one kilowatt is equivalent to about $1\frac{1}{3}$ horse power. Electric current is charged for by the watt hour. A current of one ampere, having a voltage of one volt, will furnish in the course of one hour one watt hour of energy. Energy for electric lighting is sold at the rate of about ten cents per kilowatt hour. For other purposes it is less expensive. The meters commonly used measure the amperes, volts, and time automatically, and register the electric power supplied in watt hours.

CHAPTER XXVI

LIGHT

What light does for us. — Heat keeps us warm, cooks our food, drives our engines, and in a thousand ways makes life comfortable and pleasant, but what should we do without light? How many of us could be happy even though warm and well fed if we were forced to live in the dark where the sunbeams never flicker, where the shadows never steal across the floor, and where the soft twilight cannot tell us that the day is done? Heat and light are the two most important physical factors in life; we cannot say which is the more necessary, because in the extreme cold or arctic regions man cannot live, and in the dark places where the light never penetrates man sickens and dies. Both heat and light are essential to life, and each has its own part to play in the varied existence of man and plant and animal.

Light enables us to see the world around us, makes the beautiful colors of the trees and flowers, enables us to read, is essential to the taking of photographs, gives us our moving pictures and our magic lanterns, produces the exquisite tints of stained-glass windows, and brings us the joy of the rainbow. We do not always realize that light is beneficial. Light energy sometimes causes sunburn. Our clothing and carpets fade in sunlight. But in spite of these apparently harmful effects, light energy is in reality of great value in man's constant battle against disease.

The candle. — Natural heat and light are furnished by the sun, but the absence of the sun during the evening makes

artificial light necessary, and even during the day artificial light is needed in buildings whose structure excludes the natural light of the sun. Artificial light is furnished by electricity, by gas, by oil in lamps, and in numerous other ways. Until modern times candles were the main source of light, and indeed to-day the intensity, or power, of any light is measured in candle power units, just as length is measured in yards; for example, an average gas jet gives a 10 candle power light, or is ten times as bright as a candle; an ordinary incandescent electric light gives a 16 candle power light, or furnishes sixteen times as much light as a candle. Very strong oil lamps can yield a light of 60 candle power, while the large arc lamps which flash out on the street corners are said to furnish 1200 times as much light as a single candle. Naturally all candles do not give the same amount of light, nor are all candles alike in size. The candles which decorate our tea tables are of wax, while those which serve for general use are of paraffin and tallow.

Fading illumination. — The farther we move from a light, the less strong, or intense, is the illumination which reaches us; the light of the street lamp on the corner fades and becomes dim before the middle of the block is reached, so that we look eagerly for the next lamp. The light diminishes in brightness much more rapidly than we realize, as the

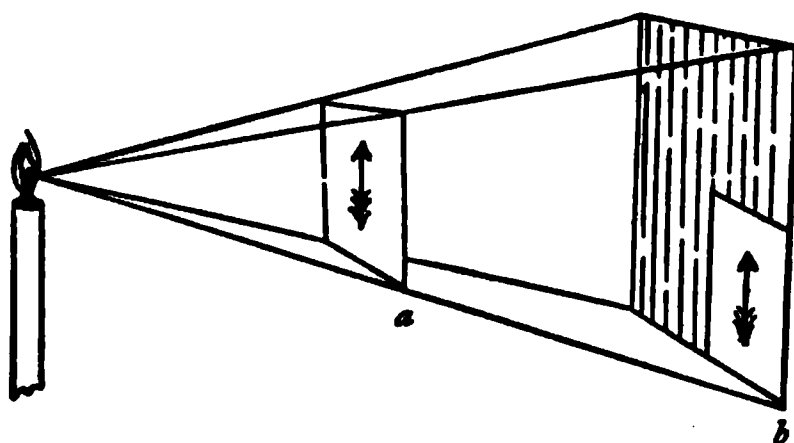


FIG. III. — A photograph at *a* receives four times as much light as when held at *b*.

following simple experiment will show. Let a single candle (Fig. III) serve as our light, and at a distance of one foot from the candle place a photograph. In this position the photograph receives a definite amount of light from the candle and has a certain brightness.

If now we place a similar photograph directly behind the first photograph and at a distance of two feet from the candle, the second photograph receives no light because the first one cuts off all the light. If, however, the first photograph is removed, the light which fell on it passes outward and spreads itself over a larger area, until at the distance of the second photograph the light spreads itself over four times as large an area as formerly. At this distance, then, the illumination on the second photograph is only one fourth as strong as it was on a similar photograph held at a distance of one foot from the candle.

The photograph or object placed at a distance of one foot from a light is well illuminated; if it is placed at a distance of two feet, the illumination is only one fourth as strong, and if the object is placed three feet away, the illumination is only one ninth as strong. This fact should make us take thought and care in the use of our eyes. We think we are sixteen times as well off with our incandescent lights as our ancestors were with simple candles, but we must reflect that our ancestors kept the candle near them, "at their elbow," so to speak, while we sit at some distance from the light and unconcernedly read or sew.

As an object recedes from a light the illumination which it receives diminishes rapidly, for the strength of the illumination is inversely proportional to the square of the distance of the object from the light. Our ancestors with a candle at a distance of one foot from a book were as well off as we are with an incandescent light four feet away.

How light travels. — We never expect to see around a corner, and if we wish to see through pinholes in three separate pieces of cardboard, we place the cardboards so that the three holes are in a straight line. When sunlight enters a dark room through a small opening, the dust particles dancing in the sun show a straight ray. If a hole is made in a card, and the card is held in front of a light, the card casts a shadow, in

the center of which is a bright spot. The light, the hole, and the bright spot are all in the same straight line. These simple observations lead us to think that light travels in a straight line.

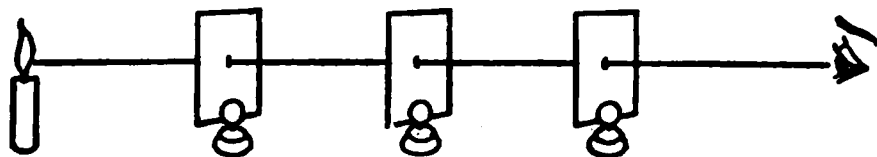


FIG. 112. — The candle cannot be seen unless the three pinholes are in a straight line.

We can always tell the direction from which light comes, either by the shadow cast or by the bright spot formed when an opening occurs in the opaque object casting the shadow. If the shadow of a tree falls towards the west, we know the sun must be in the east; if a bright spot is on the floor, we can easily locate the light whose rays stream through an opening and form the bright spot. We know that light travels in a straight line, and following the path of the beam which comes to our eyes, we are sure to locate the light.

Good and bad mirrors. — As we walk along the street, we frequently see ourselves reflected in the shop windows, in polished metal signboards, in the metal trimmings of wagons and automobiles; but in mirrors we get the best image of ourselves. We resent the image given by a piece of tin, because the reflection is distorted and does not picture us as we really are; a rough surface does not give a fair representation of us; if we want a true image of ourselves, we must use a smooth surface like a mirror as a reflector. If the water in a pond is absolutely still, we get a clear, true image of the trees, but if there are ripples on the surface, the reflection is blurred and distorted. A metal roof reflects so much light that the eyes are dazzled by it, and a whitewashed fence injures the eyes because of the glare which comes from the reflected light. Neither of these could be called mirrors, however, because although they reflect light, they reflect it so irregularly that not even a suggestion of an image can be obtained.

Most of us are sufficiently familiar with mirrors to know that the image is a duplicate of ourselves with regard to size, shape, color, and expression, but that it appears to be back of the mirror, while we are actually in front of the mirror. The image appears not only behind the mirror, but it is also exactly as far back of the mirror as we are in front of it; if we approach the mirror, the image also draws nearer; if we withdraw, it likewise recedes.

The path of light. — If a mirror or any other polished surface is held in the path of a sunbeam, some of the light is reflected, and by rotating the mirror the reflected sunbeam may be made to take any path. School children amuse themselves by reflecting sunbeams from a mirror into their companions' faces. If the companion moves his head in order to avoid the reflected beam, his tormentor moves or inclines the mirror and flashes the beam back to his victim's face.

If a mirror is held so that a ray of light strikes it in a perpendicular direction, the light is reflected backward along

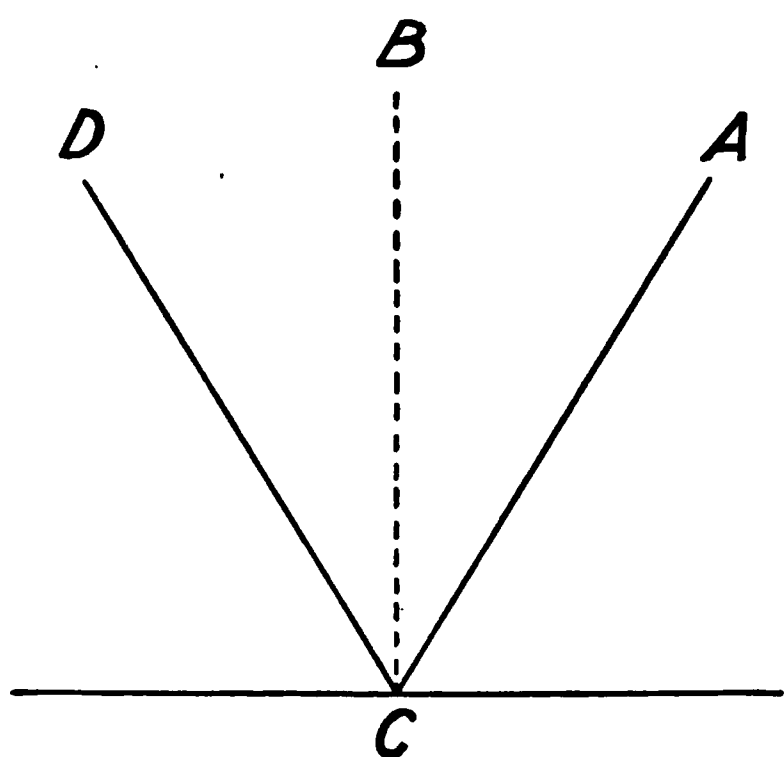


FIG. 113. — The ray AC is reflected as CD .

the path by which it came. If, however, the light makes an angle with the mirror, its direction is changed, and it leaves the mirror along a new path. By observation we learn that when a beam strikes the mirror and makes an angle of 30° with the perpendicular, the beam is reflected in such a way that its new path also makes an angle of 30° with

the perpendicular. If the sunbeam strikes the mirror at an angle of 32° with the perpendicular, the path of the reflected

ray also makes an angle of 32° with the perpendicular. The ray (AC , Fig. 113) which falls upon the mirror is called the incident ray, and the angle which the incident ray (AC) makes with the perpendicular (BC) to the mirror, at the point where the ray strikes the mirror, is called the angle of incidence. The angle formed by the reflected ray (CD) and this same perpendicular is called the angle of reflection. Observation and experiment have taught us that light is always re-

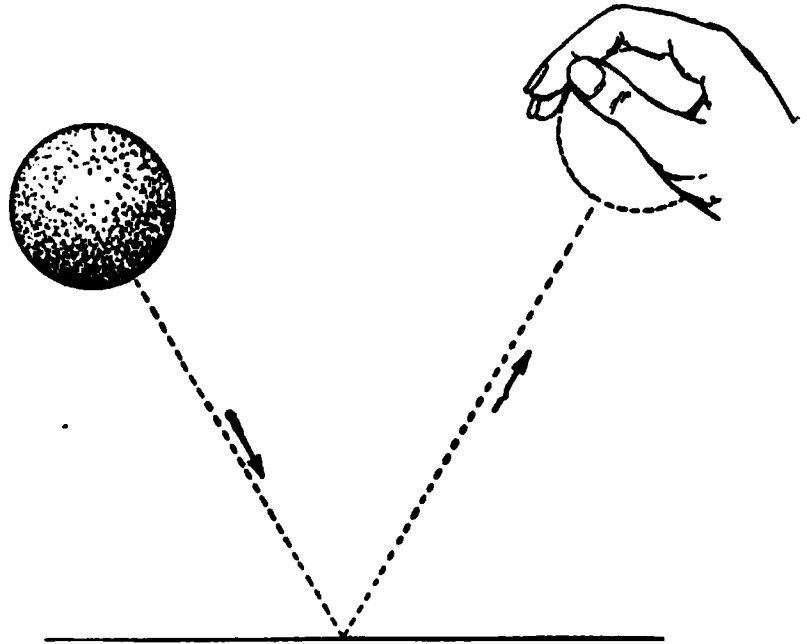


FIG. 114.—A bouncing ball illustrates the law of reflection.

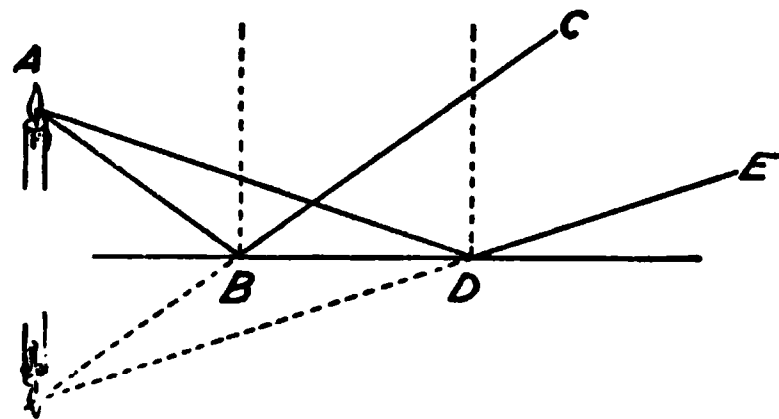


FIG. 115.—The image is a duplicate of the object, but appears to be behind the mirror.

flexed in such a way that the angle of reflection equals the angle of incidence. Light is not the only illustration we have of the law of reflection. Every child who bounces a ball makes use of this law, but he uses it unconsciously. If an elastic ball is thrown perpendicularly against the floor, it returns to the sender; if it is thrown against the floor at an angle (Fig. 114), it rebounds in the opposite direction, but always in such a way that the angle of reflection equals the angle of incidence.

Why the image seems to be behind the mirror. — If a candle is placed in front of a mirror, BD in Figure 115, one of the rays of light which leave the candle will fall upon the mirror as AB and will be reflected as BC (in such a way that the angle

of reflection equals the angle of incidence). If an observer stands at C , he will think that the point A of the candle is somewhere along the line CB extended. But the candle sends out light in all directions; one ray therefore will strike the mirror as AD and will be reflected as DE , and an observer at E will think that the point A of the candle is somewhere along the line ED . In order that both observers may be correct, that is, in order that the light may seem to be in both these directions, the image of the point A must seem to be at the intersection of the two lines. In a similar manner it can be shown that every point of the image of the candle seems to be behind the mirror.

Why objects are visible. — If the beam of light falls upon a sheet of paper, or upon a photograph, instead of upon a smooth polished surface, it is not reflected in one direction only, but in many. The surface of the paper or photograph is rough, and as a result it scatters the beam in every direction. It is hard for us to realize that a smooth sheet of paper is by no

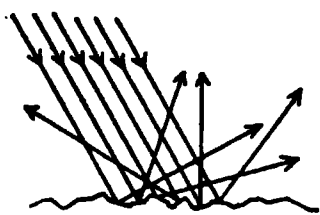


FIG. 116.

means as smooth as it looks. It is rough compared with a polished mirror. The law of reflection always holds, however, no matter what the reflecting surface is, — the angle of reflection always equals the angle of incidence.

Beams of light reflected from a smooth body are all parallel; those reflected from a rough body are inclined to each other in all sorts of ways (Fig. 116).

Hot coals, red-hot stoves, gas flames, and candles shine by their own light, and are self-luminous. Objects like chairs, tables, carpets, have no light within themselves and are visible only when they receive light from a luminous source and reflect that light in such a way that it reaches the eye. We know that these objects are not self-luminous because they are not visible in a dark room. When light from any luminous object falls upon books, desks, or dishes, it meets rough surfaces, and

hence undergoes diffuse reflection, and is scattered irregularly in all directions. No matter where the eye is, some reflected rays enter it, and the various objects are clearly seen.

Indoor illumination.—We see objects by means of light which comes from them to our eyes. If an object, such as a picture, is well illuminated, it reflects light to the eye, and we see it distinctly. If it is poorly illuminated, it reflects little light to the eye, and we see it indistinctly and with effort. Objects do not all reflect light equally well. A white object reflects most of the light which falls upon it and a moderate illumination is sufficient to light up

FIG. 117. — These two rooms receive the same amounts of light. The room at the left has dark walls and the one at the right has light walls.

a table with a white table cover. A black or dark object reflects light badly, and a strong illumination is necessary to light up dark stairways and darkly papered walls (Fig. 117). A light that would be strong enough for sewing white materials would be far from sufficient for sewing black or dark materials. A room that receives little light from out of doors should be brightly papered and furnished, otherwise it is somber, furniture does not stand out, and reading and sewing in it cause eye-strain. We are not always conscious of the strain on the eyes from working on badly lighted materials, but the strain exists and the eyes suffer. A sunny room, or one well lighted, does not need such bright paper, curtains, and furnishings, and can be arranged in darker colors without injury to the eyes.

FIG. 118. — A poorly arranged light in a dining room.

Lamps, gas jets, electric lights, should be placed in such a way that their rays are thrown upon tables, chairs, and books, and not into the eye. If a person faces a strong light when he

reads, his pupils contract and do not admit enough light from the book to make it clear and distinct (Fig. 119*b*). If a person sits so that the light falls on the book and not in his eyes, he sees the book

FIG. 119. — ^a The pupil of the eye adjusts itself to the intensity of the light. ^b

clearly because his pupils expand and allow abundant light from the book to enter his eyes (Fig. 119*a*).

The light from lamp, gas burner, or electric bulb should be scattered by globes and shades. Light that is scattered by shades and globes falls on more objects than unscattered light,

and is more restful to the eye. Every light in the home, workshop, and factory should be shaded because it is hard to see objects which are near too bright an illumination. The headlights of an approaching automobile illuminate the street, but they also blind us so that we cannot properly see the street. An unprotected lamp or electric bulb injures the eye in at least two ways: it puts upon it the strain of rejecting too strong a direct light, and the strain of seeing poorly illuminated objects (Fig. 120).

In a large room it is better to have several small lights than one large one. Several small lights do not

FIG. 120. --- A cause of eye injury.

consume any more gas or electricity than one large one. In rooms where definite objects must be clearly seen, separate lights should be placed over the objects. In a large kitchen, for example, there should be a light over the sink, and a light near the stove. It is not necessary that these should be used at the same time. During the cooking the range light should be used, during dishwashing, the sink light should be used.

The eyes are sensitive. — The eyes are very much more sensitive than many people realize. Persons have been temporarily blinded by gazing at the sun without dark glasses; electric operators have sometimes lost their sight for days because of strong electric flashes; men who examine lights rest

their eyes from time to time in order not to injure them; a prisoner whose cell faced a whitewashed fence on which the sun shone was permanently blinded by the glare. In arctic regions where the sun is brilliantly reflected from snow and ice, the glare is terrific, and the strain on the eyes is intense. Eski-

FIG. 121. — A well-lighted display at the left. The lamps are concealed. A poorly lighted window at the right. The bright unconcealed lamps produce a glare.

mos, the inhabitants of these regions, cover their eyes with wooden strips in which there is the merest slit for the passage of light to the eyes. Travelers and explorers to these regions wear dark glasses or veils as a protection to the eyes. Few people are subject to such intense strain as these, but unless we are careful we subject the eyes to strains which in time injure them permanently. Reading or sewing with the sun shining on book or material, working in the twilight, working in front of lights that are not softened and scattered by globes, working with the light shining in our faces instead of on the objects, are illustrations of common strains which should be avoided.

Glass globes for softening and scattering light are inexpensive. The best kinds are those which completely cover the brilliant part of the light. If the globes which you use do not prevent glare, protect your eyes during reading and sewing by an eye shield.

Green is a soft, restful color and most eye shields are lined with green paper or silk. For the same reason many lampshades are colored green on their outer surface. For ordinary purposes a translucent white glass globe is sufficient protection to the eyes.



FIG. 122. — Protect the eyes from direct light by means of an eye shield.

CHAPTER XXVII

REFRACTION

Bent rays of light. — A straw in a glass of lemonade seems to be broken at the surface of the liquid, the handle of a teaspoon in a cup of water appears broken, and objects seen through a

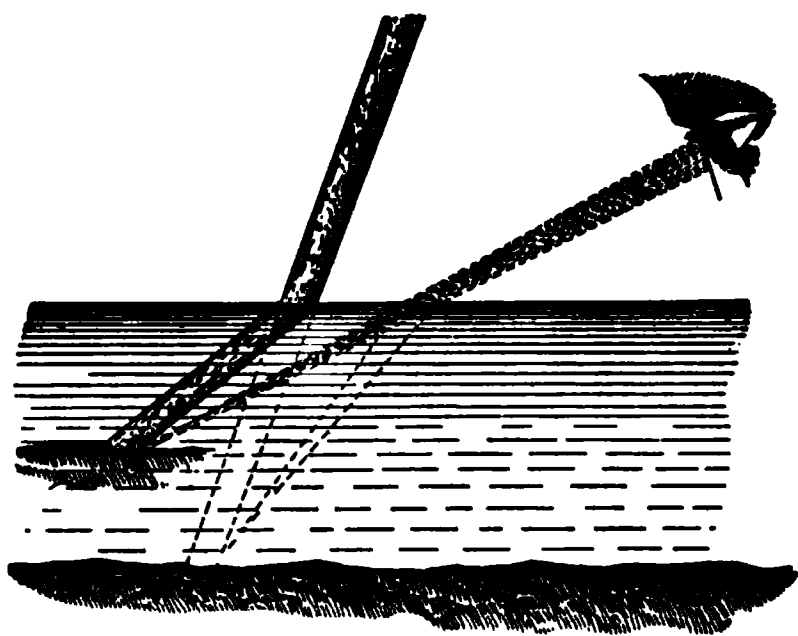


FIG. 123. — A straw or stick in water seems broken.

glass of water may seem distorted and changed in size. When light passes from air into water, or from any transparent substance into another of different density, its direction is changed, and it emerges along an entirely new path (Fig. 123). We know that light rays pass through glass, because we can see

through the window panes and through our spectacles; we know that light rays pass through water, because we can see through a glass of clear water; on the other hand, light rays cannot pass through wood, leather, metal, and the like.

Whenever light meets a transparent substance obliquely, some of it is reflected, and some of it passes onward through the medium; but the latter portion passes onward along a new path. The ray RO (Fig. 124) passes obliquely through the air to the surface of the water, but, on entering the water, it is bent or refracted and takes the new path OS . The angle AOR

is called the angle of incidence. The angle POS is called the angle of refraction.

The angle of refraction is the angle formed by the refracted ray and the perpendicular at the point where the light strikes the surface.

When light passes from air into water or glass, the refracted ray is bent toward the perpendicular, so that the angle of refraction is smaller than the angle of incidence. When a ray of light passes from water or glass into air, the refracted ray is bent away from the perpendicular so that the angle of refraction is greater than the angle of incidence.

The bending or deviation of light in its passage from one subject to another is called refraction.

Uses of refraction. — If it were not for refraction, or the deviation of light in its passage from medium to medium, the wonders and beauties of the magic lantern and the camera would be unknown to us; sun, moon, and stars could not be made to yield up their distant secrets to us in photographs; the comfort and help of spectacles would be lacking, spectacles which have helped unfold to many the rare beauties of nature, such as a clear view of clouds and sunset, of humming bee and flying bird. Books with their wealth of entertainment and information would be sealed to a large part of mankind, if glasses did not assist weak eyes.

By refraction the magnifying glass reveals objects hidden because of their minuteness, and enlarges for our careful contemplation objects otherwise barely visible. The watchmaker, unassisted by the magnifying glass, could not detect the tiny grains of dust or sand that clog the delicate wheels of our

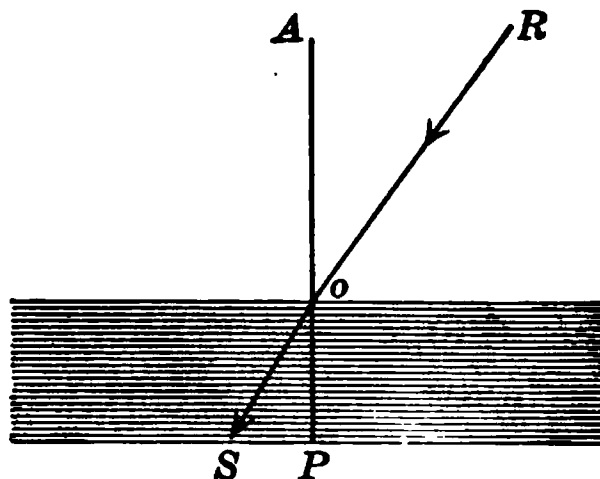


FIG. 124. — When the ray RO enters the water, its path changes to OS .

watches. The merchant, with his lens, examines the separate threads of woolen and silk fabrics to determine the strength and value of the material. The physician, with his invaluable microscope, counts the number of infinitesimal corpuscles in the blood and bases his prescription on that count; he examines the sputum of a patient to determine whether tuberculosis wastes the system. The bacteriologist with a similar instrument scrutinizes the drinking water and learns whether the dangerous typhoid germs are present. The future of medicine will depend somewhat upon the additional secrets which man is able to force from nature through the use of powerful lenses, because as lenses have in the past been the means of revealing disease germs, so in the future more powerful lenses may serve to bring to light germs yet unknown.

The window pane. — We have seen that light is bent when it passes from one medium to another of different density, and that objects viewed by refracted light do not appear in their proper positions.

When a ray of light passes through a piece of plane glass, such as a window pane, it is refracted and bent slightly from its course toward the perpendicular. When it emerges from the glass, the light is refracted away from the perpendicular and is again bent slightly. Hence, when we view objects through the window, we see them slightly displaced in position, but otherwise unchanged. The displacement caused by glass as thin as window panes is too slight to be noticed, and we are not conscious that objects are out of position.

Chandelier crystals and prisms. — When a ray of light passes through plane glass, like a window pane, it is shifted slightly. But when a beam of light passes through a triangular glass such as a chandelier crystal, its direction is greatly changed, and an object viewed through a prism is seen quite out of its true position.

Whenever light passes through a prism, it is bent toward the base of the prism, or toward the thick portion of the prism, and emerges from the prism in quite a different direction from that in which it entered (Fig. 125). Hence, when an object is looked at through a prism, it is seen quite out of place. In Figure 125 the candle seems to be at *S*, while in reality it is at *A*.

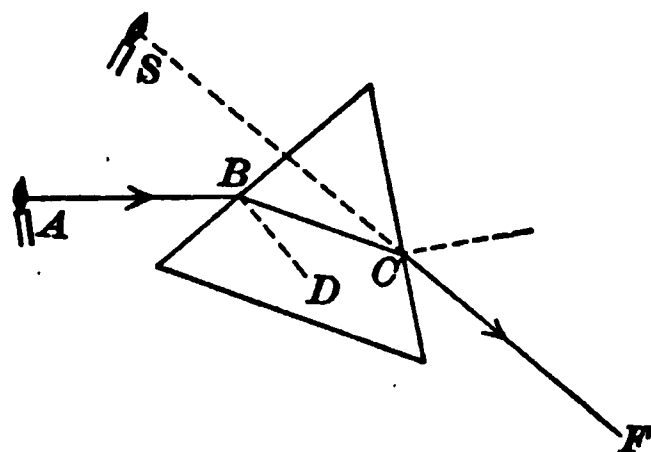


FIG. 125. — When looked at through the prism, *A* seems to be at *S*.

Lenses. — If two prisms are arranged as in Figure 126, and two parallel rays of light fall upon the prisms, the beam *A* will be bent downward and the beam *B*

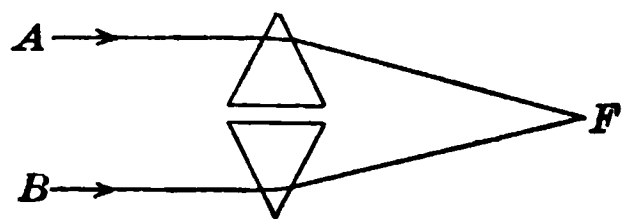


FIG. 126. — Rays of light are converged and focused at *F*.

will be bent upward toward the thick portion of the prism, and after passing through the prism the two rays will intersect at some point *F*, called a focus.

If two prisms are arranged as in Figure 127, the ray *A* will be refracted upward toward the thick end, and the ray *B* will be refracted downward toward the thick end. The two rays, on emerging, are widely separated and do not intersect.

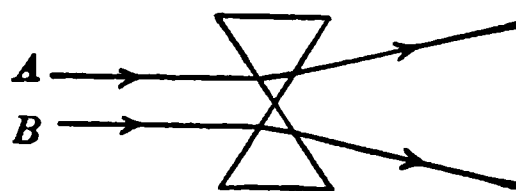


FIG. 127. — Rays of light are diverged and do not come to any real focus.

Lenses are very similar to prisms; indeed, two prisms placed as in Figure 126 and rounded off would make a very good convex lens.

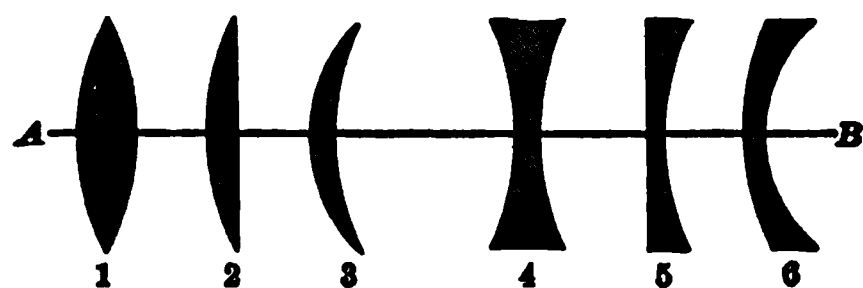


FIG. 128. — The different types of lenses.

A lens is any transparent material, but usually glass, with one or both sides curved.

The various types of lenses are shown in Fig-

ure 128. The first three types focus parallel rays at some common point F , as in Figure 126. Such lenses are called convex or converging lenses. The last three types, called concave lenses, scatter parallel rays so that they do not come to a focus,

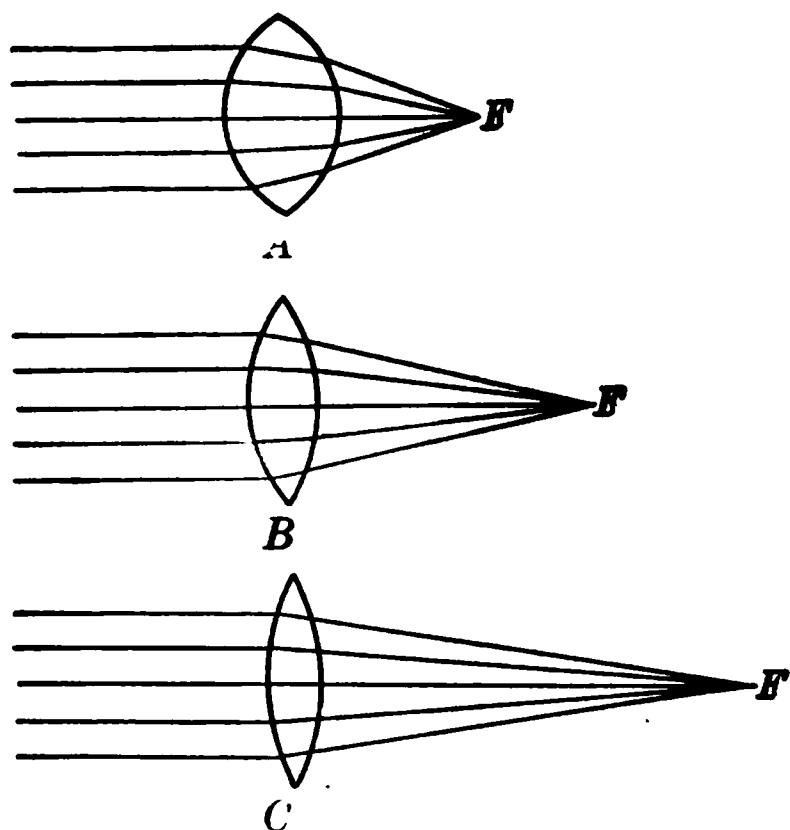


FIG. 129. — The more curved the lens, the shorter the focal length, and the nearer the focus is to the lens.

but diverge widely after passage through the lens.

The shape and material of a lens. — The main or principal focus of a lens, that is, the point at which rays parallel to the base meet, depends upon the shape of the lens. For example, a thick lens, such as A (Fig. 129), focuses the rays very near to the lens; B , which is not so thick, focuses the rays at a greater distance from the lens; and C , which is a very thin lens,

focuses the rays at a considerable distance from the lens. The distance of the principal focus from the lens is called the focal length of the lens, and from the diagrams we see that the more convex the lens, the shorter the focal length.

The position of the principal focus depends not only on the shape of the lens, but also on the refractive power of the material composing it. A lens made of ice would not deviate the rays of light so much as a lens of similar shape composed of glass. The greater the refractive power of the lens, the greater the bending, and the nearer the principal focus to the lens.

There are many different kinds of glass, and each kind of glass refracts the light differently. Flint glass contains lead; the lead gives the glass great refractive power, enabling it to

bend and scatter light in all directions. Cut glass and toilet articles are made of flint glass because of the brilliant effects caused by its great refractive power, and imitation gems are commonly nothing more than polished flint glass.

The value of lenses. — Place a convex lens near a candle (Fig. 130), and move a paper screen back and forth behind the lens. At some position of the screen, a clear enlarged image is seen. Place the candle in a new position and move the screen

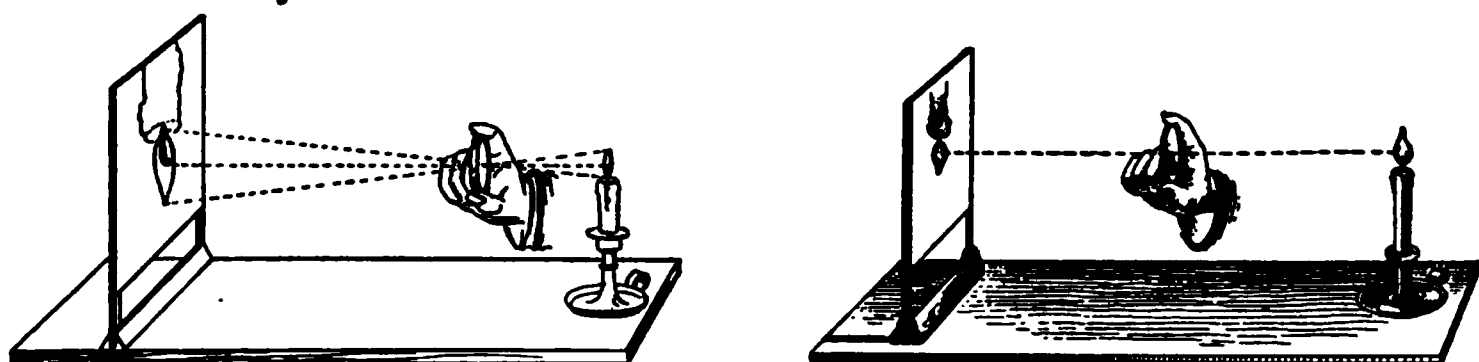


FIG. 130. — The relative sizes of image and object depend upon the position of the lens.

back and forth behind the lens. At some position of the screen a clear, but smaller image is seen. The size and position of the image depend upon the distance of the object from the lens. By means of a lens one can easily form on a visiting card a picture of a distant church steeple.

If it were not for the fact that a lens can be held at such a distance from an object as to make the image larger than the object, it would be impossible for the lens to assist the watch-maker in locating the small particles of dust which clog the wheels of the watch. If it were not for the opposite fact — that a lens can be held at such a distance from the object as to make an image smaller than the object, it would be impossible to have a photograph of a tall tree or building unless the photograph were as large as the tree itself. When a photographer takes a photograph of a person or a tree, he moves his camera until the image formed by the lens is of the desired size. By bringing the camera (really the lens of the camera) near, we

obtain a large-sized photograph; by increasing the distance between the camera and the object, a smaller photograph is obtained. The mountain top may be so far distant that in the photograph it will not appear to be greater than a small stone.

Many familiar illustrations of lenses, or curved refracting surfaces, and their work, are known to all of us. Fish globes magnify the fish that swim within. Bottles can be so shaped that they make the olives, pickles, or peaches that they contain appear larger than they really are. The fruit in bottles frequently seems too large to have gone through the neck of the bottle. The deception is due to refraction, and the material and shape of the bottle furnish a sufficient explanation.

By using lenses of various kinds, it is possible to produce an image of almost any desired size, and in any desired position.

The human eye. — We have seen how an image of a candle can be obtained on a movable screen, by means of a simple

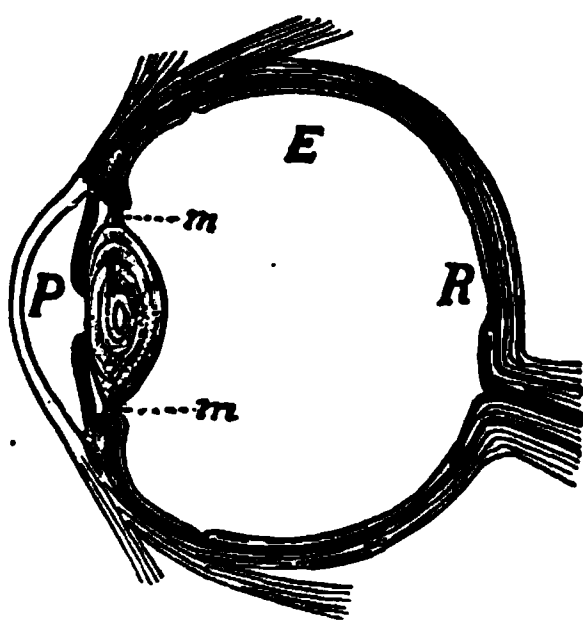


FIG. 131. — The eye.

lens. The human eye possesses a most wonderful lens and screen (Fig. 131); the lens is called the crystalline lens, and the screen is called the retina. Rays of light pass from the object through the pupil *P*, go through the crystalline lens *L*, where they are refracted, and then pass onward to the retina *R*, where they form a distinct image of the object.

We have learned that a change in the position of the object necessitated a change in the position of the screen, and that every time the object was moved the position of the screen had to be altered before a clear image of the object could be obtained. The retina of the eye cannot be moved backward and forward, as the screen was, and the crystalline lens is permanently

located directly back of the iris. How, then, does it happen that we can see clearly both near and distant objects; that the printed page which is held in the hand is visible at one second, and that the church spire on the distant horizon is visible the instant the eyes are raised from the book? How is it possible to obtain on an immovable screen by means of a simple lens two distinct images of objects at widely varying distances?

The answer to these questions is that the crystalline lens changes shape according to need. The lens is attached to the eye by means of small muscles, *m*, and it is by the action of these muscles that the lens is able to become small and thick, or large and thin; that is, to become more or less curved. When we look at near objects, the muscles act in such a way that the lens bulges out, and becomes thick in the middle and of the right curvature to focus the near object upon the screen. When we look at an object several hundred feet away, the muscles change their pull on the lens and flatten it until it is of the proper curvature for the new distance. The adjustment of the muscles is so quick and unconscious that we normally do not experience any difficulty in changing our range of view from the object at our feet to the far-distant hills and stars.

The ability of the eye to adjust itself to varying distances is called accommodation. The power of adjustment in general decreases with age, being nearly perfect in the young.

Farsightedness and nearsightedness. — A farsighted person is one who cannot see near objects so distinctly as far objects, and who in many cases cannot see near objects at all. The eyeball of a farsighted person is very short, and the retina is too close to the crystalline lens. Near objects are brought to a focus behind the retina instead of on it, and hence are not visible. Even though the muscles of accommodation do their best to bulge and thicken the lens, the rays of light are not bent sufficiently to focus sharply on the retina. In conse-

quence near objects look blurred. Farsightedness can be remedied by convex glasses, since they bend the light and bring it to a closer focus. Convex glasses, by bending the rays and

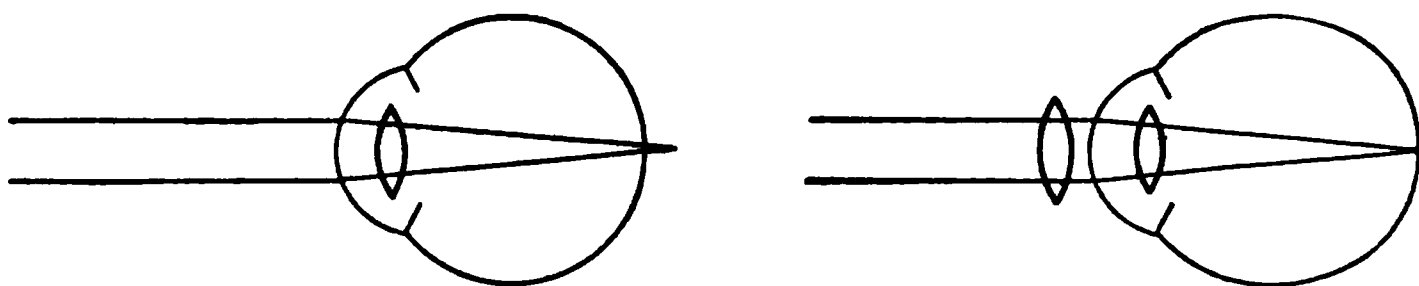


FIG. 132. — The farsighted eye. The defect is remedied by convex glasses.

bringing them to a nearer focus, overbalance a short eyeball with its tendency to focus objects behind the retina.

A nearsighted person is one who cannot see objects unless they are close to the eye. The eyeball of a nearsighted person is very wide, and the retina is too far away from the crystalline lens. Far objects are brought to a focus in front of the retina instead of on it, and hence are not visible. Even though the muscles of accommodation do their best to pull out and flatten the lens, the rays are not separated sufficiently to focus as far back as the retina. In consequence objects look blurred. Nearsightedness can be remedied by wearing concave glasses,

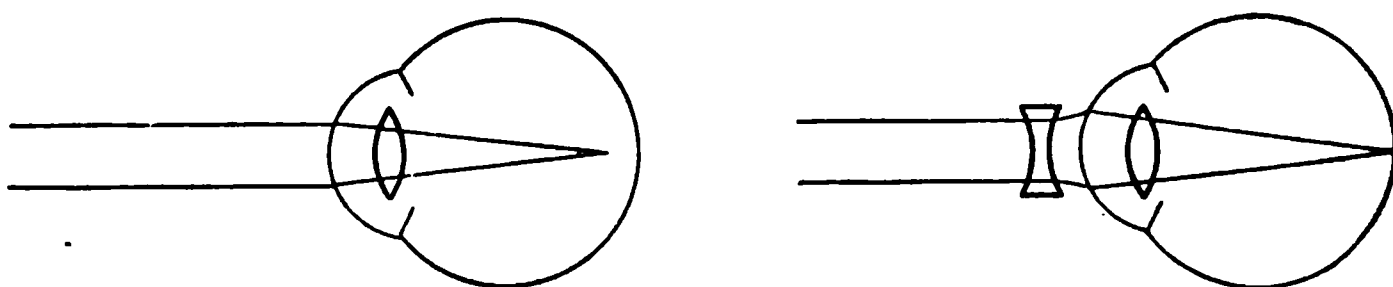


FIG. 133. — The nearsighted eye. The defect is remedied by concave glasses.

since they separate the light and move the focus farther away. Concave glasses, by separating the rays and making the focus more distant, overbalance a wide eyeball with its tendency to focus objects in front of the retina.

Headache and eyes. — Ordinarily the muscles of accommodation adjust themselves easily and quickly; if, however, they

do not, frequent and severe headaches occur as a result of too great muscular effort toward accommodation. Among young people headaches are frequently caused by overexertion of these muscles. Glasses relieve the muscles of the extra adjustment, and are effective in eliminating this cause of headache.

An exact balance is required between glasses, crystalline lens, and muscular activity, and only those who have studied the subject carefully are competent to treat so sensitive a part of the body as the eye. The least mistake in the curvature of glasses means an improper focus, increased duty for the muscles, and gradual weakening of the entire eye, followed by headache and general physical discomfort. The oculist therefore must be carefully trained for his work.

Eyestrain. — The extra work which is thrown upon the nervous system through seeing, reading, writing, and sewing with defective eyes is recognized by all physicians as an important cause of disease. The tax made upon the nervous system by the defective eye lessens the supply of energy available for other bodily use, and the general health suffers. The health is improved when proper glasses are prescribed.

Possibly the greatest danger of eyestrain is among school children. For this reason, many schools employ a physician who examines the pupils' eyes at regular intervals.

The following general precautions are worth observing:—

1. Rest the eyes when they hurt, and as far as possible do close work, such as writing, reading, sewing, or wood carving by daylight.

2. Never read in a very bright or a very dim light.

3. If light is near, have it shaded.

4. Wear an eye shield if the light produces a glare.

5. Do not rub the eyes with the fingers.

6. If the eyes are weak, bathe them in lukewarm water in which a pinch of borax has been dissolved.

CHAPTER XXVIII

PHOTOGRAPHY AND THE CHEMICAL ACTION OF LIGHT

The magic of the sun. — Ribbons and dresses washed and hung in the sun fade; when washed and hung in the shade, they are not so apt to lose their color. Clothes are laid away in drawers and hung in closets not only for protection against dust, but also against the well-known power of light to weaken color.

Many housewives lower the window shades that the wall paper may not lose its brilliancy, that the beautiful hues of velvet, satin, and plush tapestry may not be marred by loss in brilliancy and sheen. Bright carpets and rugs are sometimes bought in preference to more delicately tinted ones, because the purchaser knows that the latter will fade quickly if used in a sunny room, and will soon acquire a dull mellow tone. The bright and gay colors and the dull and somber colors are all affected by the sun, but why one should be affected more than another we do not know. Thousands of brilliant and dainty hues catch our eye in the shop and on the street, but not one of them is absolutely permanent; some may last for years, but there is always more or less fading in time.

Sunlight causes many strange, unexplained effects. If the two substances, chlorine and hydrogen, are mixed in a dark room, nothing remarkable occurs any more than though water and milk were mixed, but if a mixture of these substances is exposed to sunlight, a violent explosion occurs and an entirely new substance is formed, a compound entirely different in character from either of its components.

By some power not understood by man, the sun is able to form new substances. In the dark, chlorine and hydrogen are simply chlorine and hydrogen; in the sunlight they combine as if by magic into a totally different substance. By the same unexplained power, the sun frequently does just the opposite work; instead of combining two substances to make one new product, the sun may separate or break down some particular substance into its various elements.

For example, when the sunlight falls upon silver chloride a chemical action immediately begins. Some chlorine gas escapes. Some silver is also liberated, but it reacts with the, as yet, unaffected silver chloride and gives it a red or purple color. In time the entire mass of silver chloride is affected.

The magic wand in photography. — Let us coat one side of a glass plate with silver chloride suspended in gelatine. We must be very careful to do this in a dark room,¹ otherwise the sunlight will act upon the silver chloride before we are ready. Lay a horseshoe on the plate and carry it into the sunlight for a minute. The light causes some of the chlorine to escape, but the silver remains with the rest of the silver chloride, darkening it. All of the plate was affected by the sun except the portion protected by the horseshoe, which does not allow light to reach the plate. If, now, the plate is carried back to the dark room and the horseshoe is removed, we see on the plate an image of the horseshoe. But we must not take this image into the light, because the silver chloride which was protected by the horseshoe is still present and would be strongly affected by the least light, and would spoil the image.

But a photograph on glass, which must be carefully shielded from the light, would be neither pleasurable nor practical. If there were some way by which the unaffected silver chloride could be totally removed, we could take the plate into any

¹ That is, a room from which ordinary daylight is excluded.

light without fear. To accomplish this, the unchanged silver chloride is got rid of by "fixing," that is, by washing off the unreduced silver chloride with a solution known as "hypo." After a bath in the hypo the plate is cleansed in clear running water and left to dry. Such a process gives a clear and permanent picture on the plate.

The camera. — A camera (Fig. 134) is a light-tight box containing a movable convex lens at one end and a screen at the opposite end. Light from the object to be photographed passes through the lens, falls upon the screen, and forms an image there. If we substitute for the screen a plate coated with silver chloride, the light falling upon the

FIG. 134. — A camera.

sensitive plate will slowly change the silver chloride. If we give a sufficiently long exposure to the light an image will be formed. But this exposure would be too long to be practical, and so we must help the action of light by a chemical process. Certain substances called "developers" separate the silver from the chlorine in silver chloride. Therefore, instead of giving an exposure long enough to allow the light to complete its work on the silver chloride we give an exposure just long enough to allow the light to start the chemical action. Then the plate is placed in a developer, which quickly completes the liberation begun by the sunlight and produces the image. Silver bromide is more easily acted upon by developers than silver chloride and is now generally used for plates. Silver bromide is precipitated in gelatine with which it forms an emulsion. This silver bromide emulsion is spread over glass plates in a thin

even coating. The sensitized surfaces are then dried in dark rooms, and the plates are packed ready for sale. If you look at a plate in the light, you see the yellow, creamy film of the silver bromide emulsion.

As glass plates are heavy and inconvenient, celluloid films have almost entirely taken their place for outdoor work. If plates or films coated with the silver bromide emulsion are exposed in the camera and then carried back into the dark room, one would expect to see an image. But we are much disappointed because they show not the slightest change in appearance. This is because the exposure was too brief to produce a change that the unaided eye can detect. The developer must be used to bring out the hidden image. When the plate has been in the developer for a few seconds, the coating gradually darkens and the image slowly appears. When the image is fully developed, the unchanged silver bromide is got rid of by fixing, the plates are washed, and the negative is ready for use.

Light and shade.—Let us apply the above process to a real photograph. Suppose we wish to take the photograph of a man sitting in a chair in his library. If the man wore a gray coat, a black tie, and a white collar, these details must be faithfully represented in the photograph. How can the almost innumerable lights and shades be produced on the plate?

The white collar would send through the lens the most light to the sensitive plate; hence the silver bromide on the plate would be most changed at the place where the lens formed an image of the collar. The gray coat would not send to the lens so much light as the white collar, hence the silver bromide would be less affected by the light from the coat than by that from the collar, and at the place where the lens produced an image of the coat the silver bromide would not be changed so much as where the collar image is. The light from the face would produce a still different effect, since the light from the

face is stronger than the light from the gray coat, but less than that from a white collar. The face in the image would show less changed silver bromide than the collar, but more than the coat, because the face is lighter than the coat, but not so light as the collar. Finally, the silver bromide would be least affected by the dark tie. The wall paper in the background would affect the plate according to the brightness of the light which fell directly upon it and was reflected to the camera. When such a plate has been developed and fixed, we have the so-called negative (Fig. 135). The collar is very dark, the black tie and gray coat white, and the white tidy very dark.

FIG. 135 — A negative.

The lighter the object, such as tidy or collar, the more salt is changed, or, in other words, the greater the portion of the silver salt that is affected, and hence the darker the silver deposit on the plate at that particular spot. The plate shows all gradations of intensity — the tidy is dark, the black tie is light. The photograph is true as far as position, form, and expression are concerned, but the actual intensities are just reversed. How can this plate be transformed into a photograph true in every detail?

The perfect photograph. — Bright objects, such as the sky or a white waist, change much of the silver bromide, and hence appear dark on the negative. Dark objects, such as furniture or a black coat, change little of the bromide, and hence appear light on the negative. To obtain a true photograph, the negative is placed on a piece of sensitive photographic paper, or

paper coated with a silver salt in the same manner as the plate and films. The combination is exposed to the light. The dark portions of the negative will act as obstructions to the passage of light. But little light will pass through that part of the negative to the photographic paper, and consequently but little of the silver salt on the paper will be changed. On the other hand, the light portion of the negative will allow free and easy passage of the light rays, which fall upon the photographic paper and will change much more of the silver. Thus it is that dark places in the negative produce light places in the positive or real photograph (Fig. 136), and that light places in the negative produce dark places in the positive; all intermediate grades are likewise represented with their proper gradations of intensity.

If properly treated, a negative remains good for years, and serves for an indefinite number of positives or true photographs.

FIG. 136. - A positive or true photograph

Light and disease. — The far-reaching effect that light has upon some inanimate objects, such as photographic films and clothes, leads us to inquire into the relation which exists between light and living things. We know from daily observation that plants must have light in order to thrive and grow. A healthy plant brought into a dark room soon loses its vigor and freshness, and becomes yellow and drooping. Plants do not all agree as to the amount of light they require, for some, like the fern and the arbutus, grow best in moderate light, while others, like Indian corn, need the strong, full beams of the

sun. But nearly all common plants, whatever they are, sicken and die if deprived of sunlight for a long time. This is likewise true in the animal world. During long transportation, animals are sometimes necessarily confined in dark cars, with the result that many deaths occur, even though the car is well aired and ventilated and the food supply good.

FIG. 137. — Stems and leaves of oxalis growing toward the light.

In addition to the plants and animals which we see, there are many strange unseen ones floating in the atmosphere around us, lying in the dust of corner and closet, growing in the water we drink, and thronging decayed vegetable and animal matter. Every one knows that mildew and vermin do damage in the home and in the field, but very few understand that, in addition to these visible enemies of man, there are swarms of invisible plants and animals some of which do far more damage, both directly and indirectly, than the seen and familiar enemies. All such very small plants and animals are known as *microorganisms*. Not all microorganisms are harmful; some are our friends and are as helpful to us as are cultivated plants and domesticated animals. Among the most important of the microorganisms are bacteria, which include among their number both friend and foe. Although sunlight is essential to the growth of most plants and animals, it destroys bacteria.

Light and growing plants. — All plants, except a few like bacteria and molds, need light for growth and development. This is largely because light by its chemical action enables

plants to transform substances absorbed from the air and the ground into starches and proteins. Plants through their leaves take carbon dioxide from the air, and through their roots plants absorb mineral matter and water from the soil. But carbon dioxide, water, and mineral matter must be changed before they can be used to nourish the plant and to build up tissue. When light shines upon a leaf, the green coloring matter, or chlorophyll, in the leaf absorbs some of the energy of the light rays, and by means of it transforms the raw materials, water and carbon dioxide and mineral matter, into starch and protein. Without light chlorophyll is powerless to transform raw materials into food substances, and is like a mill without power to run it. Food making by plants ceases at night when sunlight is shut off from the earth and begins again in the morning when the sun's beams again fall upon the earth; in winter when there are no leaves to make food, trees and shrubs are inactive and live upon food made the preceding summer and stored away in stems and roots. Both chlorophyll and sunlight are necessary to food making and plants like bacteria and molds, which do not contain chlorophyll, cannot make food. Such plants steal their nourishment, and thus live and thrive; the mold which grows on jelly lives at the expense of the jelly; the bacteria which cause diphtheria live at the expense of throat tissue.

Heat and light as companions. — Bodies which glow and give out light are hot; the stove which glows with a warm red is hot and fiery; smoldering wood is black and lifeless; glowing coals are far hotter than black ones. The stained glass window softens and mellows the bright light of the sun, but it also shuts out some of the warmth of the sun's rays; the shady side of the street spares our eyes the intense glare of the sun, but may chill us by the absence of heat; the setting sun takes away light and heat and leaves the air chilly. In summer we lower the shades

and close the blinds in order to keep the house cool, because the exclusion of light means the exclusion of some heat; in winter we open the blinds and raise the shades in order that the sun may stream into the room and flood it with light and warmth. Our illumination, whether it be oil lamp or gas jet or electric

light, carries with it heat; indeed, so much heat that we refrain from making a light on a warm summer's night because of the heat which it unavoidably furnishes. The heat of the sun and the light of the sun seem boon companions. The heat of the sun as well as the light of the sun is essential to the growth of plants. If spring, with its

FIG. 138. — Vegetation in northern Russia.
The trees are nearly 100 years old.

warm days, is late, seeds are late in sprouting; if the summer is cold, crops are slow and poor. Indian corn will not mature and give full big ears unless hot sun shines down on the field in its growing season. Far north, where the sun's rays bring little heat to the land, plants are few and stunted (Fig. 138). In the polar regions, where the temperature is always low, plants do not grow at all.

CHAPTER XXIX

COLOR

The rainbow. — One of the most beautiful and well-known phenomena in nature is the rainbow. From time immemorial it has been considered Jehovah's signal to mankind that the storm is over and that the sunshine will remain. Practically every one knows that a rainbow can be seen only when the sun's rays shine upon a mist of tiny drops of water. It is these tiny drops which by their refraction and their scattering of light produce the rainbow in the heavens.

The exquisite tints of the rainbow can be seen if we look at an object through a prism or chandelier crystal, and a very simple experiment enables us to produce on the wall of a room the exact colors of the rainbow in all their beauty.

How to produce rainbow colors. *The spectrum.* — When a beam of sunlight is admitted into a dark room through a narrow opening in the shade, and falls upon a prism, as shown in Figure 139, a beautiful band of colors appears on the opposite wall of the room. The ray of light which entered the room as ordinary sunlight has not only been refracted and bent from its straight path, but it has been spread out into a band of colors similar to those of the rainbow.

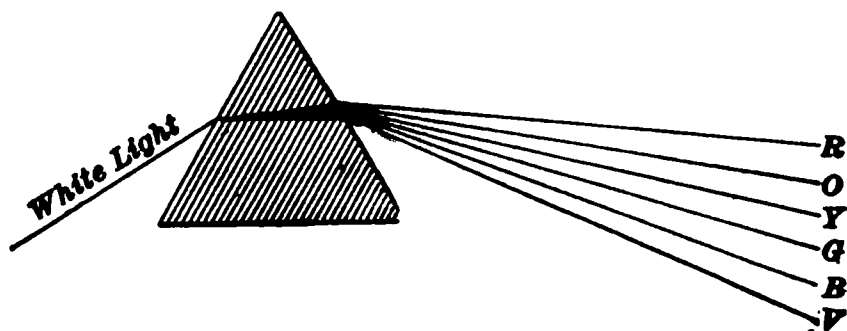


FIG. 139. — White light is a mixture of lights of rainbow colors.

Whenever light passes through a prism or lens, it is dispersed

or separated into all the colors which it contains, and a band of colors produced in this way is called a spectrum. If we examine such a spectrum, we find the following colors in order, each color imperceptibly fading into the next: violet, blue, green, yellow, orange, red.

Color. — If a piece of red glass is held in the spectrum, all the colors on the wall disappear except the red, and instead of a beautiful spectrum of all colors there is seen the red color alone. The red glass does not allow the passage through it of any light except red light; all other colors are absorbed by the red glass and do not reach the eye. Only the red ray passes through the red glass, reaches the eye, and produces a sensation of color.

If a piece of blue glass is substituted for the red glass, the blue light is seen and all the other colors disappear. If both blue and red pieces of glass are held in the path of the beam, so that the light must pass through first one and then the other, the entire spectrum disappears and no color remains. The blue glass absorbs the various rays with the exception of the blue ones, and the red glass will not allow these blue rays to pass through it. No light passes to the eye.

An emerald looks green because it freely transmits green, but absorbs the other colors of which ordinary daylight is composed. A diamond appears white because it allows the passage through it of all the various rays; this is likewise true of water and window panes.

Stained-glass windows owe their charm and beauty to the presence in the glass of various dyes and pigments which absorb in different amounts some colors from white light and transmit others. These pigments or dyes are added to the glass while it is in the molten state, and the beauty of a stained-glass window depends largely upon the richness and the delicacy of the pigments used.

Reflected light. Opaque objects. — The reason why most objects are visible to us is because of the light diffusely reflected from them. A white object, such as a sheet of paper, a whitewashed fence, or a tablecloth, absorbs little of the light which falls upon it, but reflects nearly all, thus producing the sensation of white. A red carpet absorbs the light rays incident upon it except the red rays, and these it reflects to the eye.

Any substance or object which reflects none of the rays which fall upon it, but absorbs all, appears black. Coal and tar and soot are good illustrations of opaque objects which absorb all the light that falls upon them.

Primary and complementary colors. — Strange and unexpected facts await us at every turn in science. If a cardboard disk, painted one third red, one third green, and one third blue, is rapidly rotated, its color is white. Moreover, by the mixture of these three colors in various quantities, any color of the spectrum, such as yellow, indigo, or orange, may be obtained. Red, green, and blue are called primary or essential hues, because all known tints of color may be produced by mixing these lights in the proper proportions; for example, purple is obtained by blending red and blue, and orange by blending blue and green.

White can be obtained by blending certain colors in pairs: blue and yellow lights blend into white; and green and purple when mixed also give white. Two colors which blend to produce white are called complementary colors. Complementary colors are the greatest possible contrast to each other and sometimes give pleasing effects when used near each other in decorations. Ordinarily, however, striking contrasts in color are not desirable in either clothes or household furnishings.

As every one knows, combining lights is very different from mixing paints. While blue and yellow lights combine to produce white, blue and yellow paints combine to produce green.

When pigments are blended, not all of the colors are combined in the mixture; some are neutralized by absorption and are lost from the final combination. No one should attempt to mix paints who has not some knowledge of the action of pigments on each other. If you wish to combine paints to secure a definite color, try out the colors by mixing small amounts first.

How and why colors change. Matching colors. — Most women prefer to shop in the morning or early afternoon when the sunlight illuminates shops and factories, and when gas and electricity do not throw their spell over colors. Practically all people know that ribbons and ties, trimmings and dresses, frequently look different at night from what they do in the daytime. It is not safe to match colors by artificial light; cloth which looks red by night may be almost purple by day. Indeed, the color of an object depends upon the color of the light that falls upon it. Strange sights are seen on the Fourth of July when variously colored fireworks are blazing. The child with a white blouse appears first red, then blue, then green, according as his powders burn red, blue, or green. The face of the child changes from its normal healthy hue to a brilliant red and then to ghastly shades.

Suppose, for example, that a white hat is held in red light. The characteristic of white objects is their ability to reflect *all* the various rays that fall upon them. Here, however, the only light which falls upon the white hat is red light, hence the only light which the hat has to reflect is red light and the hat consequently appears red. Similarly, if a white hat is placed in a blue light, it reflects all the light which falls upon it, namely, blue light, and appears blue. If a red hat is held in a red light, it is seen in its proper color. If a red hat is held in a blue light, it appears black; it cannot reflect any of the blue light because that is all absorbed and there is no red light to reflect.

CHAPTER XXX

ARTIFICIAL LIGHTING

WE seldom consider what life would be without our wonderful methods of illumination which turn night into day, and prolong the hours of work and pleasure. Yet it was not until the nineteenth century that the marvelous change was made from the short-lived candle to the more enduring oil lamp. Before the coming of the lamp, even in large cities like Paris, the only artificial light to guide the belated traveler at night was the candle kept burning in an occasional window.

With the invention of the kerosene lamp came more efficient lighting of home and street, and with the advent of gas and electricity came a light so effective that the hours of business, manufacture, and pleasure could be extended far beyond the setting of the sun.

The candle. — In the early days of civilization, man secured modest illumination by burning wicks soaked in fats. Liquid fat was poured into a metal vessel and a wick was inserted in an opening in the cover. Later, this crude device was replaced by the more convenient candle. Originally, candles were made by dipping a wick into melted tallow, withdrawing it, allowing the adhered tallow to harden, and repeating the dipping until a satisfactory thickness was obtained. The more modern method consists in pouring a fatty preparation into a mold, at the center of which a wick has been placed.

A wick, when lighted, burns for a brief interval with a faint, uncertain light; almost immediately, however, the intensity of the light increases and the illumination remains good as

long as the candle lasts. The heat of the burning wick melts the fatty substance near it, and this liquid fat is quickly sucked up into the burning wick. The heat of the flaming wick is sufficient to change most of this liquid into a gas, that is, to vaporize the liquid; and to set fire to the gas thus formed. These heated gases burn with a bright yellow flame.

• Small particles of carbon are also set free from the unvaporized fatty liquid, and these, on coming in contact with the oxygen of the surrounding air, glow with an intense heat and increase the brightness of the candle flame.

The oil lamp. — The simple candle of our ancestors was later replaced by the oil lamp which gives a brighter, steadier,

and more permanent illumination (Fig. 140). The principle of the lamp is similar to that of the candle, except that the wick is saturated with kerosene or oil rather than with fat. The heat from the burning wick is sufficient to change the oil into a gas and then to set fire to the gas. By placing a lamp chimney over the burning wick, a constant and uniform draft of air is secured around the blazing gases, and hence a

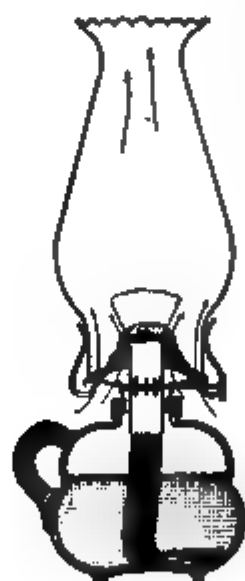


FIG. 140. — The oil lamp.

steady, unflickering light is obtained. If the quantity of air which enters at the bottom of the chimney is insufficient, some of the carbon particles are not burned and form soot. A lamp "smokes" when the air which reaches the wick is insufficient to burn to incandescence the rapidly formed carbon particles:

this explains the danger of turning a lamp wick too high and producing more carbon particles than can be oxidized by the air admitted at the bottom of the lamp chimney.

One great disadvantage of oil lamps and oil stoves is that they cannot be carried safely from place to place. It is almost impossible to carry a lamp without jarring it and without spilling oil over the edges. The flame soon spreads from the wick to the overflowing oil, and in consequence the lamp blazes and an explosion may result. Candles, on the other hand, are safe from explosion; the grease which drops from them is unpleasant but not dangerous.

The illumination from a shaded oil lamp is soft and agreeable, but the trimming of the wicks, the refilling of the bowls, and the cleaning of the chimneys require time and labor. For this reason the introduction of gas met with widespread success. The illumination from an ordinary gas jet is also stronger than that from an ordinary lamp, and the stronger illumination added to the greater convenience made gas a very popular source of light.

Gas burners and gas mantles. — For a long time, the only gas flame used was that from a fishtail burner (Fig. 141). Recently, however, the fishtail burner has been widely replaced by incandescent mantles, such as the Welsbach. The principle of the incandescent mantle is very simple. When certain substances, such as thorium and cerium, are heated, they do not melt or vaporize, but glow with an intensely bright light. Mr. Welsbach made use of this fact to secure a burner in which the illumination depends upon the glowing of an incandescent, solid mantle, rather than upon the blazing of a burning gas. He made a cylindrical mantle of thin fabric (Fig. 142), and then soaked it in a

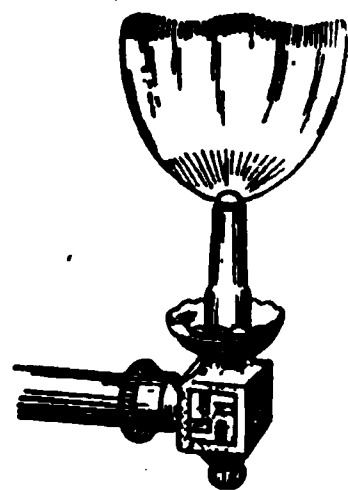


FIG. 141. — Fishtail burner.

solution of thorium and cerium until it became saturated with the chemicals. The mantle thus impregnated with thorium and cerium is placed on the gas jet and supported by a Welsbach fixture, but before the gas is turned on, a lighted match is held to the mantle in order to burn away the thin fabric. After the fabric has been burned away, there remains a coarse gauze mantle of the desired chemicals. If now the gas cock is opened, and the escaping gas is ignited, the heat of the flame raises the mantle to incandescence and produces a brilliant light. A very small amount of burning gas is sufficient to raise the mantle to incandescence, and hence, by this method, intense light is secured at little cost.

FIG. 142. — A gas mantle.



FIG. 143. — Inverted gas burner and mantle.

When a Welsbach burner is fastened to the gas jet, the pressure of the gas is lessened by a mechanical device and less gas escapes and burns. By actual experiment, it has been found that an ordinary burner

consumes about five times as much gas per candle power as the best incandescent burner and hence is about five times as expensive. One objection to the mantles is their tendency to break. But if they are carefully adjusted to the burner, and are not roughly jarred in use, they

last many months. Since the best quality can be purchased at twenty-five cents, the expense of renewing the mantles is only slight.

Natural gas. — Animal and vegetable matter buried in the depth of the earth sometimes undergoes natural distillation,

and as a result gas is formed. The gas produced in this way is called natural gas. It is a cheap source of illumination, but is found in relatively few localities and only in limited quantity.

Acetylene gas. — The distillation of soft coal into illuminating gas is not practicable on a small scale and so illuminating gas is seldom seen in small towns, villages, and farming regions. An illumination which is widely used in thinly settled regions is acetylene, a gas made from calcium carbide. Originally calcium carbide was expensive, but in 1892 it was discovered that it could be cheaply made by fusing lime and coal together in the intense heat of an electric furnace. As a result of that discovery, calcium carbide was soon made on a large scale and sold at a moderate price. The cheapness of calcium carbide has made it possible for the isolated farmhouse to discard oil lamps and to have a private gas system. When the hard, dry crystals of calcium carbide are put in water, they give off acetylene, a colorless gas which burns with a brilliant white flame. Put bits of calcium carbide in a bottle and close it with a cork in which is fitted a glass tube, as shown in Figure 144. Pour a little water into the glass tube. As soon as the water reaches the calcium carbide, bubbles of gas form and escape into the air. The escaping gas may be ignited by a burning match held near the mouth of the tube. When chemical action between the water and carbide has ceased, and gas bubbles have stopped forming, slaked lime is left.

When calcium carbide is used as a source of illumination, the crystals are mechanically dropped into a tank containing water, and the gas generated is automatically collected in a small sliding tank, whence it passes through pipes to the various rooms. The slaked lime, formed while the gas was generated, collects at the bottom of the tanks and is removed from time to time.



FIG. 144. —
A simple
laboratory
method of
making acet-
ylene gas.

The cost of an acetylene generator is about \$50 for a small house, and the cost of maintenance is not more than that of lamps. The generator does not require filling oftener than once a week, and the labor is less than that required for oil lamps. In a house in which there were twenty burners, the tanks were filled with water and carbide but once a fortnight. Acetylene is seldom used in large cities, but it is very widely used in small communities and is particularly convenient in more or less remote summer residences.

Electric lights. — The most recent and the most convenient lighting is that obtained by electricity. A fine, hairlike filament within a glass bulb is raised to incandescence by the heat of an electric current.

CHAPTER XXXI

SOUND

How sounds are caused and carried to us. — All the information which we possess of the world around us comes to us through the use of the senses of sight, hearing, taste, touch, and smell. Of the five senses, sight and hearing are generally considered the most valuable. The sounds we hear are due to motion of some kind, a sudden noise is traced to the fall of an object, to an explosion, or to a collision; in fact, is due to the motion of matter. A piano gives out sound whenever a player strikes the keys and sets in motion the various wires within the piano; speech and song are caused by the motion of chest, vocal cords, and lips.

If a large dinner bell is rung, its motion or vibration may be felt on touching it with the finger. When a tuning fork is made to give forth sound by striking it against the knee, and is then touched to the surface of water, small sprays of

water are thrown out, showing that the prongs of the fork are in rapid motion. In most cases sound reaches the ear through the air; but air is not the only medium through which sound is carried. A loud noise startles fish and causes them to dart away, so we conclude that the sound reaches them through the

FIG. 145. — Sprays of water show that the fork is in motion.

water. An Indian puts his ear to the ground in order to detect distant footsteps, because sounds too faint to be heard through the air are comparatively clear when transmitted through the earth. A gentle tapping at one end of a long table can be distinctly heard at the opposite end if the ear is pressed against the table; if the ear is removed from the wood, the sound of tapping is much fainter, showing that wood transmits sound more readily than air.

The velocity of sound. — A sounding body always disturbs and throws into vibration the air around it, and the air particles which receive motion from a sounding body transmit their motion to neighboring particles, these in turn to the next adjacent particles, and so on until the motion has traveled to very great distances. But the transmission of motion from particle to particle requires time. If the distance is short, so that few air particles are involved, the time required for transmission is very brief and the sound is heard at practically the instant it is made. Ordinarily we are not conscious that it requires time for sound to travel from its source to our ears, because the distance covered is too short. At other times we recognize that there is a delay; for example, thunder reaches our ears after the lightning which caused the thunder has completely disappeared. If the storm is near, the interval of time between the lightning and the thunder is brief, because the sound does not have far to travel; if the storm is distant, the interval is much longer, corresponding to the greater distance through which the sound travels.

Echo. — If one shouts out of doors, the sound is sometimes heard a second time a moment or two later. This is because sound is reflected when it strikes a large obstructing surface. If the sound waves from the shout meet a cliff or a mountain, they are reflected back, and on reaching the ear produce a later sensation of sound.

By observation it has been found that the ear cannot distinguish sounds which are less than one tenth of a second apart; that is, if two sounds follow each other at an interval less than one tenth of a second, the ear recognizes not two sounds, but one. This explains why a speaker can be heard better indoors than in the open air. In the average building, the walls are so close that the reflected waves have but a short distance to travel, and hence reach the ear at practically the same time as those which come directly from the speaker. In the open, there are no reflecting walls or surfaces, and the original sound has no reënforcement from reflection.

If the reflected waves reach the ear too late to blend with the original sound, that is, come later than one tenth of a second after the first impression, an echo is heard. What we call the rolling of thunder is really the reflection and re-reflection of the original thunder from cloud and cliff.

Some halls are so large that the reflected sounds cause a confusion of echoes, but this difficulty can be lessened by hanging draperies, which break the reflection.

Noise and music. — When the rapid motions which produce sound are irregular, we hear noise; when the motions are regular and definite, we have a musical tone. The rattling of carriage wheels on stones, the roar of waves, the rustling of leaves are noise, not music.

To produce music a body must impart short, quick shocks to the air, and must impart these shocks with unerring regularity and strength. A flickering light irritates the eye; a flickering sound or noise irritates the ear; both are painful because of the sudden and abrupt changes which they cause, the former on the eye, the latter on the ear.

The only thing essential for the production of a musical sound is that the pulses which reach the ear shall be rapid and regular; it is immaterial how they are produced. If a toothed

wheel is mounted and slowly rotated, and a stiff card is held against the teeth of the wheel, a distinct rap is heard every time the card strikes the wheel. But if the wheel is rotated rapidly, the ear ceases to hear the various taps and recognizes a deep continuous musical tone. The blending of the individual taps, occurring at regular intervals, has produced a sustained musical tone. A similar result is obtained if a card is drawn slowly and then rapidly over the teeth of a comb.

MUSICAL INSTRUMENTS

Musical instruments may be divided into three groups according to the different ways in which their tones are produced:—

First. The stringed instruments in which sound is produced by the vibration of stretched strings, as in the piano, violin, guitar, mandolin.

Second. The wind instruments in which sound is produced by the vibrations of definite columns of air, as in the organ, flute, cornet, trombone.

Third. The percussion instruments, in which sound is produced by the motion of stretched membranes, as in the drum, or by the motion of metal disks, as in the tambourines and cymbals.

Stringed instruments. — When the lid of a piano is open, numerous wires are seen within: some long, some short, some coarse, some fine. Beneath each wire is a small felt hammer connected with the keys in such a way that when a key is pressed, a string is struck by a hammer and is thrown into vibration, thereby producing a tone.

If we press the lowest key, that is, the key giving forth the lowest pitch, we see that the longest wire is struck and set into vibration; if we press the highest key, that is, the key giving the highest pitch, we see that the shortest wire is struck. In addition, it is seen that the short wires which produce the

high tones are fine, while the long wires which produce the low tones are coarse. The shorter and finer the wire, the higher the pitch of the tone produced; the longer and coarser the wire, the lower the pitch of the tone produced.

The constant striking of the hammers against the strings stretches and loosens them and alters their pitch; for this reason each string is fastened to a screw which can be turned so as to tighten the string or to loosen it if necessary. The tuning of the piano is the adjustment of the strings so that each shall produce a tone of the right pitch. When the strings are tightened, the pitch rises; when the strings are loosened, the pitch falls.

What has been said of the piano applies as well to the violin, guitar, and mandolin. In the latter instruments the strings are few in number, generally four, as against eighty-eight in the piano; the hammer of the piano is replaced in the violin by the bow, and in the guitar by the fingers; varying pitches on any one string are obtained by sliding a finger of the left hand along the wire, and thus altering its length.

Frequent tuning is necessary, because the fine adjustments are easily disturbed. The piano is the best protected of all the stringed instruments, being inclosed by a heavy framework, even when in use.

Strings and their tones. — Fasten a violin string to a wooden frame or box, as shown in Figure 147, stretching it by means

FIG. 146. — Front view of an open piano.

of some convenient weight; then lay a yardstick along the box in order that the lengths may be determined accurately. If the stretched string is plucked with the fingers or bowed with the violin bow, a clear musical sound of definite pitch will be

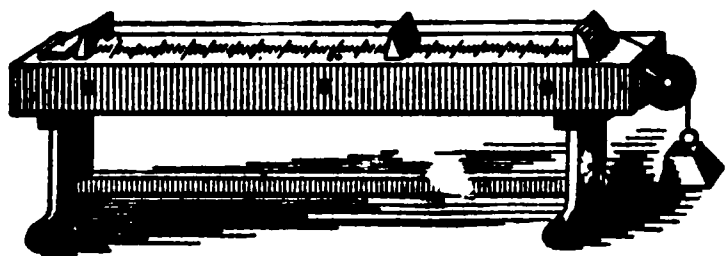


FIG. 147. — The length of a string influences the pitch.

produced. Now divide the string into two equal parts by inserting the bridge midway between the two ends; and pluck either half as before.

The note given forth is of a decidedly higher pitch, and is the octave of the note sounded by the entire wire. If now the bridge is placed so that the string is divided into two unequal portions such as 1 : 3 and 2 : 3, and the shorter portion is plucked, the pitch will be still higher; the shorter the length plucked, the higher the pitch produced. This movable bridge corresponds to the finger of the violinist; the finger slides back and forth along the string, thus changing the length of the bowed portion and producing variations in pitch.

If there were but one string, only one pitch could be sounded at any one time; the additional strings of the violin allow of the simultaneous production of several tones.

Wind instruments. — In the so-called wind instruments, such as clarinet and flute, sound is produced by vibrating columns of air inclosed in tubes or pipes of different lengths. The air column is thrown into vibration either directly, by blowing across a narrow opening at one end of a pipe, as in the case of the whistle, or indirectly, by exciting vibrations in a thin strip of wood or metal, called a reed, which in turn communicates its vibrations to the air column within.



FIG. 148. — Open organ pipes.

The shorter the air column, the higher the pitch. With a pipe of fixed length, for example, the clarinet (Fig. 149, 1), different pitches are obtained by pressing keys which open holes in the tube and thus shorten or lengthen the vibrating air column and produce a rise or fall in pitch. Changes in pitch are also produced by variation in the player's breathing. By blowing hard or gently, the number of vibrations of the reed is increased or decreased and the pitch is altered.

In the oboe (Fig. 149, 2) the vibrating air column is set into motion by means of two thin pieces of wood or metal placed in the mouthpiece of the tube. Variations in pitch are produced, as in the clarinet, by means of stops and varied breathing. In the flute, the air is set into motion by direct blowing from the mouth, as is done, for instance, when we blow into a bottle or key.



FIG. 149. — 1, clarinet; 2, oboe; 3, flute.

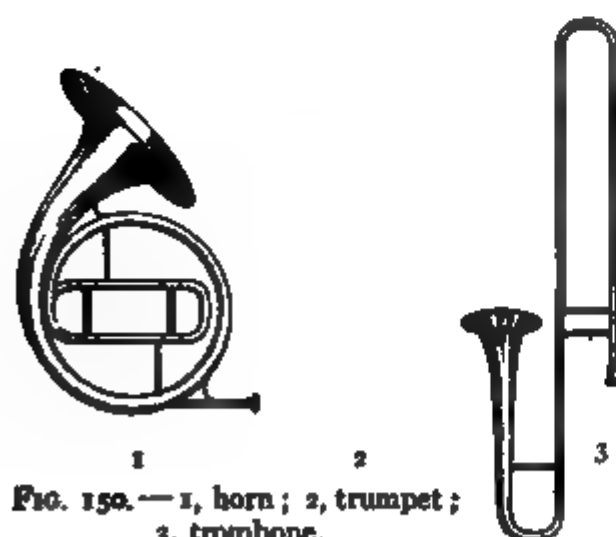


FIG. 150. — 1, horn; 2, trumpet; 3, trombone.

The sound given out by organ pipes is due to air which is set into vibration as it is blown across a sharp edge at the opening of a narrow tube. This vibration is communicated to the air within the organ pipe. In order to obtain the different pitches, pipes of different

lengths are used. The mechanism of the organ is such that pressing a key allows the air to rush into the communicating

pipe and a sound is produced characteristic of the length of the pipe.

In the brass wind instruments, such as horn, trombone, and trumpet, the lips of the player vibrate and excite the air within. Varying pitches are obtained partly by the varying wind pressure of the musician; if he breathes fast, the pitch rises; if he breathes slowly, the pitch falls. All of these instruments, however, except the trombone possess some valves which, on being pressed, vary the length of the tube and alter the pitch accordingly. In the trombone, valves are replaced by a section which slides in and out and shortens or lengthens the tube.

CHAPTER XXXII

HOW MACHINES LIGHTEN LABOR

Labor-saving devices. — To primitive man belonged the arduous tasks of outdoor life, such as the clearing of paths through the wilderness, the hauling of material, the breaking up of the hard soil of barren fields into soft loam ready to receive the seed, and the harvesting of the ripe grain.

The more intelligent races among men soon learned to help themselves in these tasks. For example, our ancestors soon learned to pry stones out of the ground (Fig. 151) rather than to undertake the almost impossible task of lifting them out of the earth in which they were embedded; to swing fallen trees away from a path by means of rope attached to one end rather than to attempt to remove them single handed; to pitch hay rather than to lift it; to clear a field with a rake rather than with the hands; to carry heavy loads in wheelbarrows (Fig. 152) rather than on the shoulders; to roll barrels up a plank (Fig. 153); and to raise weights by ropes. In every case, whether in the lifting of stones, or the felling of trees, or the transportation of heavy weights, or the digging of the ground, man used his brain in the invention of mechanical

FIG. 151. — Prying a stone out of the ground.

devices which would relieve muscular strain and lighten physical labor.

If all mankind had depended upon physical strength only, the world to-day would be in the condition prevalent in parts of Africa, Asia, and South America, where the natives loosen the soil with their hands or with crude implements (Fig. 154), and transport huge weights on their shoulders and heads.

Any mechanical device (Figs. 152, 153, 155, 156), whereby man's work⁴ can be more conveniently done, is called a machine. The machine itself never does any work — it merely en-

FIG. 152 — The wheelbarrow lightens labor.

ables man to use his own efforts to better advantage.

When do we work? — Whenever, as a result of effort or force, an object is moved, work is done. If you lift a knapsack from the floor to the table, you do work because you use force and move the knapsack through a distance equal to the height of the table. If the knapsack were twice as heavy, you would exert twice as much force to raise it to the same height, and hence you would do double the work. If you raised the knapsack twice the distance,

FIG. 153. — Rolling barrels up a plank.

—say to your shoulders instead of to the level of the table, — you would do twice the work, because while you would exert the same force, you would continue it through double the distance.

Lifting heavy weights through great distances is not the only way in which work is done. Painting, chopping wood, hammering, plowing, washing, scrubbing, sewing, are all forms of work. In painting, the moving brush spreads paint over a surface; in chopping wood, the descending ax cleaves the wood asunder; in scrubbing, the wet mop rubbed over the floor carries dirt away; in every conceivable form of work, force and motion occur.

A man does work when he walks, a woman does work when she rocks in a chair—although here the work is less than in walk-

FIG. 154. — Crude method of farming.

ing. On a windy day the work done in walking is greater than normal. The wind resists our progress, and we must exert more force in order to cover the same distance. Walking through a plowed or rough field is much more tiring than walking on a smooth road, because, while the distance covered may be the same, the effort put forth is greater, and more work is done. Always the greater the resistance encountered, the greater the force required, and the greater the work done.

The work done by a boy who raises a 5-pound knapsack to his shoulder would be 5×4 , or 20, providing his shoulders were 4 feet from the ground.

The amount of work done depends upon the force used and the distance covered, and hence we can say that

$$\text{Work} = \text{force multiplied by distance,}$$

or $W = f \times d.$

Machines. — A glance into our machine shops, our factories, and even our homes shows how widespread is the use of complex machinery. But all machines, however complicated in appearance, are in reality but modifications and combinations of one or more of four simple machines devised long ago by our remote ancestors. These simple devices are known to-day, as (1) the lever, represented by a crowbar, a pitchfork; (2) the inclined plane, represented by the plank upon which barrels are rolled into a wagon; (3) the pulley, represented by almost any contrivance for the raising of furniture to upper stories; (4) the wheel and axle, represented by cogwheels and coffee grinders.

FIG. 155. — Primitive method of grinding corn.

Suppose a 1600-pound boulder which is embedded in the ground is needed for the tower of a building. The problem of the builder is to get the heavy boulder out of the ground, to load it on a wagon for transportation, and, finally, to raise it to the tower. Obviously, he cannot do this alone; the greatest amount of force of which he is capable would not suffice to accomplish any one of these tasks. How, then, does he help himself and

perform the impossible? Simply, by the use of some of the machine types mentioned above, illustrations of which are known in a general way to every schoolboy. The very knife with which a stick is whittled is a machine.

The lever. — Balance a foot rule, containing a hole at its middle point F , as shown in Figure 157. If now a weight of 1 pound is suspended from the bar at some point, say 12, the balance is disturbed, and the bar swings about the point F as a center. The balance can be regained by suspending an equivalent weight at the opposite end of the bar, or by applying a 2-pound weight at a point 3 inches to the left of F . In the latter case a force of 1 pound actually balances a force of 2 pounds, but the 1-pound weight is twice as far from the point of suspension as is the 2-pound weight. The small weight makes up in distance what it lacks in magnitude.

FIG. 156. — Separating rice grains by fanning.

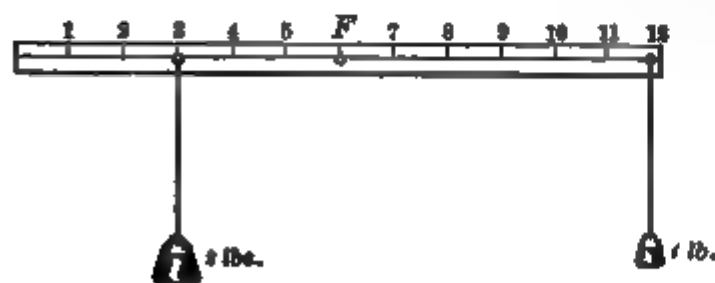


FIG. 157. — The principle of the lever.

Such an arrangement of a rod or bar is called a lever. In any form of lever there are three things to be considered: the point where the weight rests, the point where the force acts,

and the point, called the fulcrum, about which the rod rotates. The distance from the force to the fulcrum is called the force

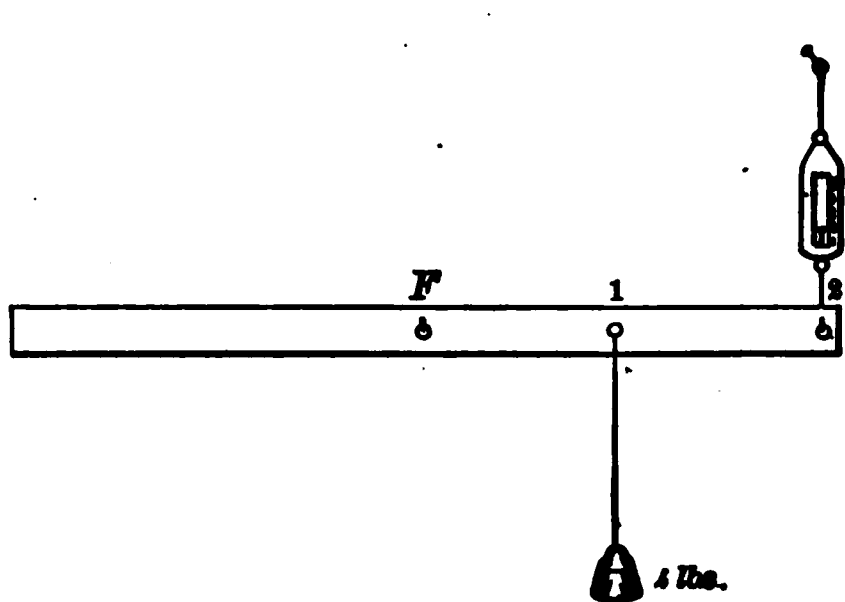
arm. The distance from the weight to the fulcrum is called the weight arm; and it is a law of levers, as well as of all other machines, that the force multiplied by the length of the force arm must equal the weight multiplied by the length of the weight arm.

$$\text{Force} \times \text{force arm} = \text{weight} \times \text{weight arm}.$$

A force of 1 pound at a distance of 6, or with a force arm 6, will balance a weight of 2 pounds with a weight arm 3; that is,

$$1 \times 6 = 2 \times 3.$$

Similarly a force of 10 pounds may be made to sustain a weight of 100 pounds, providing the force arm is 10 times longer than



the weight arm; and a force arm of 800 pounds, at a distance of 10 feet from the fulcrum, may be made to sustain a weight of 8000 pounds, providing the weight is 1 foot from the fulcrum.

Applications of the lever.

FIG. 158. — A slightly different form of lever.

— By means of a lever, a 1600-pound boulder can be easily pried out of the ground. Let the lever, any strong metal bar, be supported on a stone which serves as fulcrum. Then if a man exerts his force at the end of the rod, somewhat as in Figure 151, the force arm will be the distance from the stone or fulcrum to the end of the bar, and the weight arm will be the distance from the fulcrum to the boulder itself. The man pushes down with a force of 200 pounds, but with that amount succeeds in prying up the 1600-pound boulder. If, however, we know that the force arm is 8 times as long as the weight arm, it is quite evident that the smaller force

is compensated for by the greater distance through which it acts.

At first sight it seems as though the man's work were done for him by the machine. But this is not so. The man must lower his end of the lever 4 feet in order to raise the boulder 6 inches out of the ground. He does not at any time exert a large force, but he accomplishes his purpose by exerting a small force continuously through a correspondingly greater distance. He finds it easier to exert a force of 200 pounds continuously until his end has moved 4 feet rather than to exert a force of 1600 pounds on the boulder and move it 6 inches.

By the time the stone has been raised, the man has done as much work as though the stone had been raised directly. But his inability to put forth sufficient muscular force to raise the boulder directly would have made im-



FIG. 159. — The wheelbarrow lightens labor.

possible a task which was easily accomplished when by means of the lever he extended his small force through a greater distance.

The wheelbarrow as a lever. — The principle of the lever is always the same; but the relative position of the important points may vary. For example, the fulcrum is sometimes at one end, the force at the opposite end, and the weight to be lifted between them.

Suspend a stick with a hole at its center as in Figure 158, and hang a 4-pound weight at a distance of 1 foot from the fulcrum, supporting the load by means of a spring balance 2 feet from

the fulcrum. The pointer on the spring balance shows that the force required to balance the 4-pound load is but 2 pounds.

The force is 2 feet from the fulcrum, and the weight (4) is 1 foot from the fulcrum, so that

$$\text{Force} \times \text{distance} = \text{weight} \times \text{distance},$$

or

$$2 \times 2 = 4 \times 1.$$

Move the 4-pound weight so that it is very near the fulcrum, say but 6 inches from it; then the spring balance regis-

ters a force only one fourth as great as the weight which it suspends. In other words, a force of 1 at a distance of 24 inches (2 feet) is equivalent to a force of 4 at a distance of 6 inches.

One of the most useful levers of this type is the wheelbarrow (Fig. 159). The fulcrum is at the wheel, the force is at the handles, the

FIG. 160. — A modified wheelbarrow.

weight is on the wheelbarrow. If the load is halfway from the fulcrum to the man's hands, the man has to lift with a force equal to one half the load. If the load is one fourth as far from the fulcrum as the man's hands, he needs to lift with a force only one fourth as great as that of the load.

This shows that in loading a wheelbarrow, it is important to arrange the load as near to the wheel as possible.

The nutcracker (Fig. 161) is an illustration of a double lever

of the wheelbarrow kind; the nearer the nut is to the fulcrum, the easier the cracking.

Hammers (Fig. 162) tack lifters, scissors, forceps, are important levers, and if you will notice how many different levers (Fig. 163) are used by all classes of men, you will understand how valuable a machine this simple device is.

The inclined plane.—A man wishes to load the 1600-pound boulder on a wagon, and proceeds to do it by means of a plank, as in Figure 153. Such an arrangement is called an inclined plane.

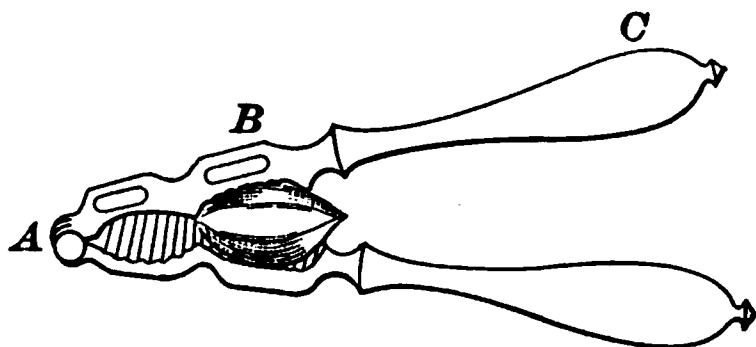


FIG. 161. — The nutcracker is a lever.

The advantage of an inclined plane can be seen by the following experiment. Select a smooth board 4 feet long and prop it so that the end *A* (Fig. 164) is 1 foot above the level of the table; the length of the incline is then 4 times as great as its height. Fasten a metal roller to a spring balance and observe its weight. Then pull the roller uniformly upward along the plank and notice what the pull is on the balance, being careful always to hold the balance parallel to the incline.

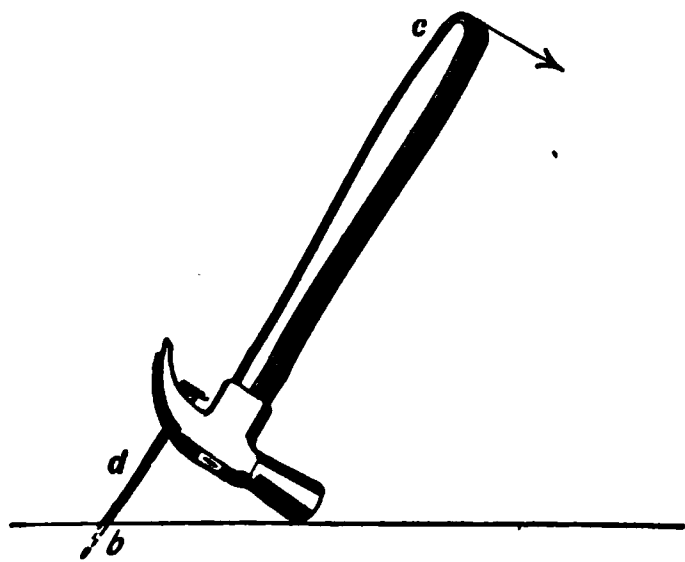


FIG. 162. — The hand exerts a small force over a long distance and draws out a nail.

When the roller is raised along the incline, the balance registers a pull only one fourth as great as the actual weight of the roller. That is, when the roller weighs 12, a force of 3 suffices to raise it to the height *A* along the incline; but the smaller force must be applied throughout the entire length of the incline. In

many cases, it is preferable to exert a force of 30 pounds, for example, over the distance CA than a force of 120 pounds over the shorter distance BA .

Prop the board so that the end A is 2 feet above the table level; that is, arrange the inclined plane in such a way that its length is twice as great as its height. In that case the steady pull on the balance will be one half the weight of the roller; or a force of 6 pounds will suffice to raise the 12-pound roller.

FIG. 163. — Primitive man tried to lighten his task by balancing his burden.

The steeper the incline, the greater is the force necessary to raise a weight; whereas if the incline is small, the necessary lifting force is much reduced. On an inclined plane whose length is ten times its height, the lifting force is reduced to one tenth the weight of the load. The advantage of an incline depends upon the relative length and height, or is equal to the ratio of the length to the height.

Application. — By the use of an inclined plank a strong man can load the 1600-pound boulder on a wagon. Suppose the floor of the wagon is 2 feet above the ground, then if an 8-foot plank is used, 400 pounds of force will suffice to raise the boulder. But the man

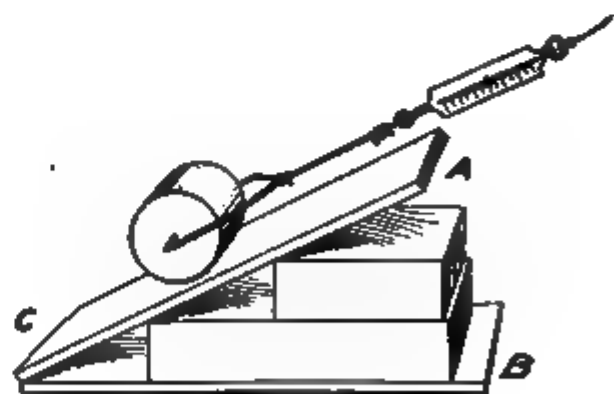


FIG. 164. — Less force is required to raise the roller along the incline than to raise it to A directly.

will have to push with this force against the boulder while it moves over the entire length of the plank.

Since work is equal to force multiplied by distance, the man has done work represented by 400×8 , or 3200. This is exactly the amount of work which would have been necessary to raise the boulder directly. A man even of enormous strength could not lift such a weight (1600 lb.) even an inch directly, but a strong man can furnish the smaller force (400) over a distance of 8 feet; hence, while the machine does not lessen the total amount of work required of a man, it creates a new distribution of work and makes possible, and even easy, results which otherwise would be impossible by human agency.

Railroads and highways. — The problem of the incline is important to engineers who construct highways and lay railroad tracks. It requires tremendous force to pull a load up

FIG. 165. — A well-graded railroad bed.

grade, and most of us are familiar with the struggling horse and the puffing locomotive. For this reason engineers, wherever possible, level down the steep places, and reduce the strain as far as possible.

The slope of the road is called its **grade** and the **grade** itself is simply the number of feet the hill rises per mile. A road a mile long (5280 feet) has a grade of 132 if the crest of the hill is 132 feet above the level at which the road started.

In such an incline, the ratio of length to height is $5280 \div 132$, or 40. Hence in order to pull a train of cars to the summit, the engine would need to exert a continuous pull equal to one fortieth of the combined weight of the train.

FIG 166. — A long, gradual ascent is better than a shorter, steeper one.

If, on the other hand, the ascent had been gradual, so that the grade was 66 feet per mile, a pull from the engine of one eightieth of the combined weight would have sufficed.

Because of these facts, engineers spend large sums of money in grading down railroad beds and in making them as nearly level as possible. In mountainous regions where the land cannot be leveled, the railroad winds around the mountain in a long gradual ascent.

The wedge. — If an inclined plane is pushed underneath or within an object, it serves as a wedge. Usually a wedge consists of two inclined planes (Fig. 167).

A chisel, an ax, and the prongs of a fork are illustrations of wedges. Perhaps the most universal form of a wedge is our common pin. Can you explain how this is a wedge?



The screw. — Another valuable and indispensable form of the inclined

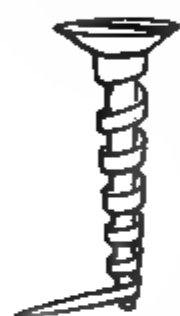


FIG. 168. —
A screw as
a simple
machine.

plane is the screw. This consists of a metal rod around which passes a ridge. Figure 168 shows clearly that a screw is simply a rod around which (in effect) an inclined plane has been wrapped.

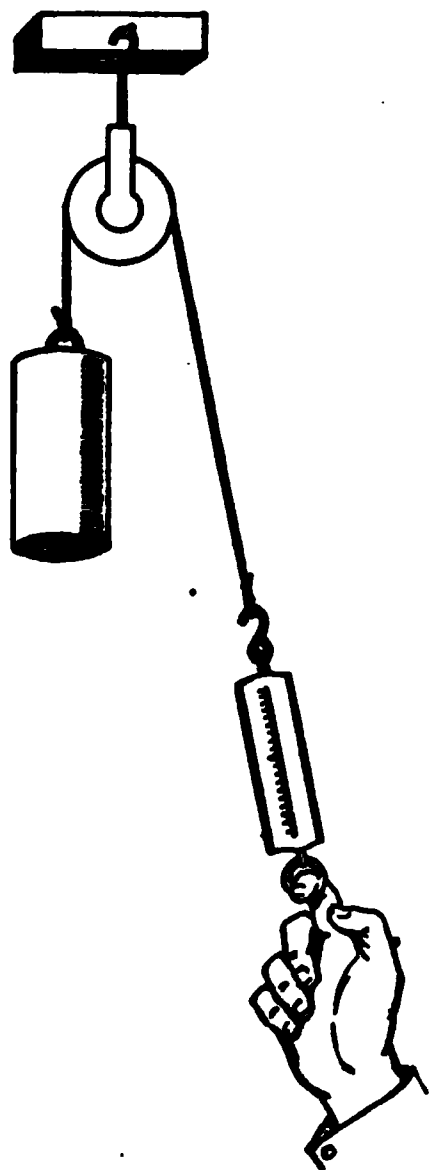
FIG. 167. — By means of a wedge,
the stump is split.

The ridge encircling the screw is called the thread, and the distance between two successive threads is called the pitch. It is easy to see that the closer the threads and the smaller the pitch, the greater is the advantage of the screw, and the less is the force needed in overcoming resistance. A corkscrew is a familiar illustration of the screw.



FIG. 169. — Useful applications of the screw.

Pulleys. — The pulley, another of the machines, is merely a grooved wheel around which a cord passes. It is sometimes more convenient to move a load in one direction rather than in another, and the pulley in its simplest form enables us to do this. In order to raise a flag to the top of a mast, it is not



necessary to climb the mast, and so pull up the flag. The same result is accomplished by attaching the flag to a movable string, somewhat as in Figure 170, and pulling from below. As the string is pulled down, the flag rises.

If we employ a stationary pulley, as in Figure 170, the force required to balance the load is as large as the load itself. The only advantage is that a force in one direction produces motion in another direction. Such a pulley is known as a fixed pulley.

Movable pulleys. — By the use of a movable pulley, we are able to support a heavy weight by a small force. In Figure 171, the spring balance supports only one half the entire load, the remaining half being borne by the hook to which the string is attached.

FIG. 170. — By means of a fixed pulley, a force in one direction produces motion in the opposite direction.

The weight is divided equally between the two parts of the string which passes around the pulley, so that each strand bears only one half of the burden.

We have seen in our study of the lever and the inclined plane that an increase in force is always accompanied by a decrease in distance, and in the case of the pulley we naturally look for a similar result. If you raise the balance (Fig. 171) 12 feet, you will find that the weight rises only 6 feet; if you raise the balance 24 inches, you will find that the weight rises

12 inches. You must exercise a force of 100 pounds over 12 feet of space in order to raise a weight of 200 pounds a distance of 6 feet. Whether we raise 100 pounds through 12 feet or 200 pounds through 6 feet the total work done is the same; but the pulley enables those who cannot furnish a force of 200 pounds for the space of 6 feet to accomplish the task by furnishing 100 pounds for the space of 12 feet.

Combination of pulleys.

—A combination of pulleys called block and tackle is used where very heavy loads are to be moved. In Figure 172 the upper block of pulleys is fixed, the lower block is movable, and one continuous rope passes around the various pulleys. The load is supported by 6 strands, and each strand

FIG. 171. — A movable pulley lightens labor.

A

W

FIG. 172. — An effective arrangement of pulleys known as block and tackle.

bears one sixth of the load. If the hand pulls with a force of 1 pound at *P*, it can raise a load of 6 pounds at *W*, but the hand will have to pull downward 6 feet at *P* in order to raise the load at *W* 1 foot.

Practical application. — In our childhood many of us saw with wonder the appearance and disappearance of flags flying at the tops of high masts, but observation soon taught us that the flags were raised by pulleys. In tenements, where there is no yard for the family washing, clothes often appear flapping in mid-air. This seems most marvelous until we learn that the lines are pulled back and forth by pulleys

at the window and at a distant support. By means of pulleys, awnings are raised and lowered. The use of pulleys by furniture movers is familiar to every wide-awake observer on the streets.

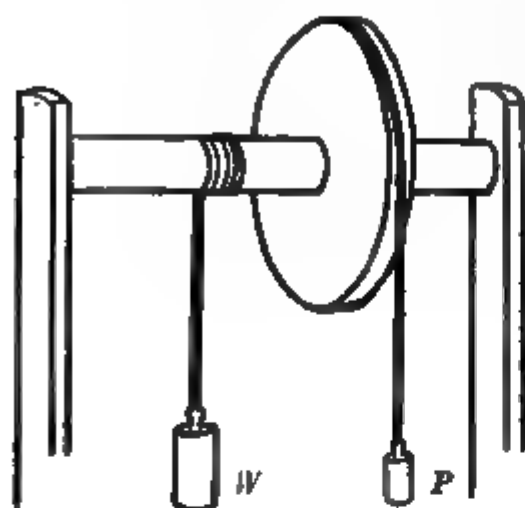


FIG. 173. — The wheel and axle.

Wheel and axle. — The wheel and axle consists of a large wheel and a small axle so fastened that they rotate together (Fig. 173).

When the large wheel makes one revolution, *P* falls a distance equal to the circumference of the wheel. While *P* moves downward, *W* likewise moves, but its

motion is upward, and the distance it moves is small, being equal only to the circumference of the small axle. But a small force at *P* will sustain a larger force at *W*. If the circumference of the large wheel is 40 inches, and that of the small wheel 10 inches, a load of 100 at *W* can be sustained by a force of 25 at *P*. The advantage of the wheel and axle depends upon the relative size of the two parts, that is, upon the circumference of the wheel as compared with the circumference of the axle. Figure 174 illustrates a wheel and axle used in the home.

Application. Windlass, cog-wheels. — In the old-fashioned windlass used in farming districts, the large wheel (Fig. 173) is replaced by a handle which, when turned, describes a circle. Such an arrangement is equivalent

FIG. 174. — Bread mixer.

to wheel and axle. The capstan used on shipboard for raising the anchor has the same principle. The kitchen coffee grinder and the meat chopper are other familiar illustrations.

Cogwheels are modifications of the wheel and axle. Teeth cut in A fit into similar teeth cut in B , and rotation of A causes rotation of B . But several revolutions of the smaller wheel are necessary in order to turn the larger wheel through one complete revolution. If the radius of A is one half that of B , two revolutions of A will be required to turn B through one revolution.

Experiment shows that a weight W (Fig. 175), attached to a cogwheel of radius 3, can be raised by a force P , one third as large, applied to a cogwheel of radius 1. There is thus a great increase in force. But the speed with which W is raised is only one third the speed with which the small wheel rotates, or increase in power has been at the decrease of speed.

FIG. 175. — Cogwheels.

This is a very common method for raising heavy weights by small force.

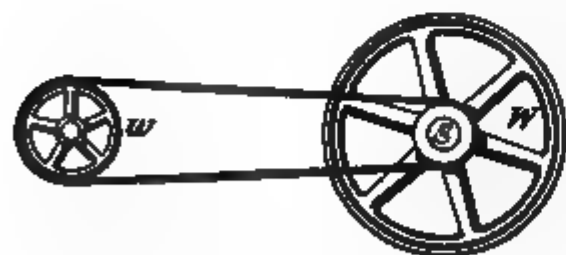


FIG. 176. — By means of a belt, motion can be transferred from place to place.

Cogwheels can be made to give speed at the decrease of force. A heavy weight W , attached to B , will in its slow fall cause rapid rotation of A , and hence rapid rise of P . It is true that P , the load raised,

will be less than W , the force exerted, but if speed is our aim, this machine serves our purpose admirably.

An extremely important form of wheel and axle is that in

which the two wheels are connected by belts, as in Figure 176. Rotation of W induces rotation of w , and a small force at W is able to overcome a large force at w . An advantage of the belt connection is that power at one place can be transmitted over a considerable distance and utilized in another place.

Compound machines. — Out of the few simple machines mentioned in the preceding sections has developed the complex machinery of to-day. By a combination of screw and lever, for example, we obtain the advantage due to each device, and some compound machines have been made which combine all the various kinds of simple machines, and in this way multiply their advantage manyfold.

A relatively simple compound machine called the crane (Fig. 179) may be seen almost any day on the street, or wherever heavy weights are being lifted. Two of the most common illustrations of compound machines are the sewing machine and the typewriter. Can you pick out the simple machines in each?

Measurement of work. — We have learned that the amount of work done depends upon the force exerted, and the distance covered. A man who raises 5 pounds a height of 5 feet does far more work than a man who raises 5 ounces a height of 5 inches, but the product of force by distance is 25 in each case. There is difficulty because we have not selected an arbitrary unit of work. The unit of work used in practical affairs is the foot pound. It is defined as the work done when a force of 1 pound acts through a distance of 1 foot. A man who moves 8

FIG. 177. — A simple derrick for raising weights.

pounds through 6 feet does 48 foot pounds of work, while a man who moves 8 ounces ($\frac{1}{2}$ pound) through 6 inches ($\frac{1}{2}$ foot) does only one fourth of a foot pound of work.

The power or the speed with which work is done. — A man can load a wagon more quickly than a growing boy. The work done by the one is equal to

the work done by the other, but the man is more powerful and does the work in a shorter time. An engine which hoists a 50-pound weight in 1 second is much more powerful than a man who requires 50 seconds for the same task. In estimating the

FIG. 178. — The typewriter is a compound machine.

value of a working agent, whether animal or mechanical, we must consider not only the work done, but the speed with which it is done.

The rate at which a machine is able to accomplish a unit of work is called *power*, and the unit of power customarily used is the horse power. Any power which can do 550 foot pounds

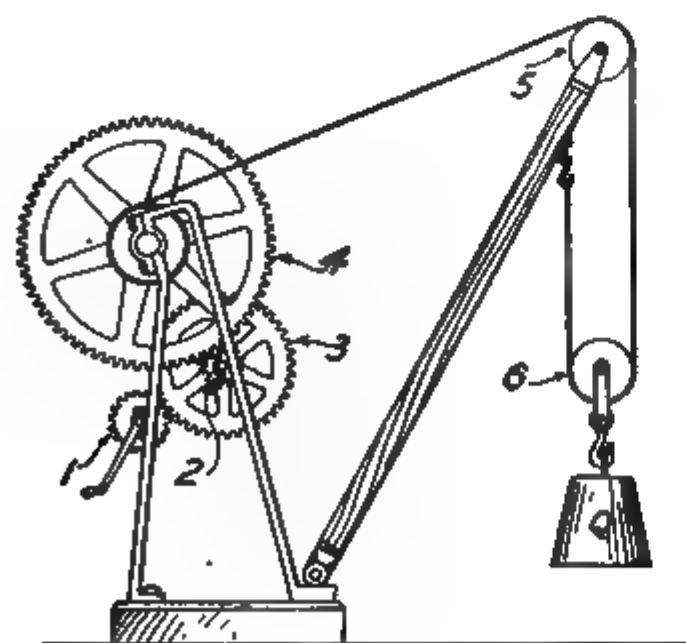


FIG. 179. — A traveling crane.

of work per second is said to be one horse power (H.P.). This unit was chosen by James Watt, the inventor of a steam engine, when he was in need of a unit with which to compare the new source of power, the engine, with his old source of power, the horse. Although called a horse power, it is greater than the power of an average horse.

An ordinary man can do one sixth of a horse power. The average locomotive of a railroad has more than 500 H.P., while the combined engines of an ocean liner may have as high as 70,000 H.P.

FIG. 180. — A farm engine putting in a crop. A very complex machine.

Waste work and efficient work. — In our study of machines we omitted a factor which in practical cases cannot be ignored, namely, friction. No surface can be made perfectly smooth, and when a barrel rolls over an incline, or a rope passes over a pulley, or a cogwheel turns its neighbor, there is rubbing and slipping and sliding. Motion is thus hindered, and the effective value of the acting force is lessened. In order to secure the desired result, it is necessary to apply a force in excess of that calculated. This extra force, which must be supplied if friction is to be counteracted, is in reality waste work.

If the force required by a machine is 150 pounds, while that

calculated as necessary is 100 pounds, the loss due to friction is 50 pounds, and the machine, instead of being thoroughly efficient, is only two thirds efficient.

Machinists make every effort to eliminate from a machine the waste due to friction, leveling and grinding to the most perfect smoothness and adjustment every part of the machine. When the machine is in use, friction may be further reduced by the use of lubricating oil. But friction can never be totally eliminated, and machines of even the finest construction lose by friction some of their efficiency, while poorly constructed ones lose by friction as much as one half of their efficiency.

Man's strength not sufficient for machines. — A machine, an inert mass of metal and wood, cannot of itself do any work, but can only distribute the energy brought to it. Fortunately it is this energy should be contributed because the store of energy is very small in comparison with that required to run locomotives, automobiles, and ships. Perhaps the greatest value of machines is that they enable man to put to use of energy other than his own.

FIG. 181

Figure 181 shows one way in which a horse's energy can be utilized in lifting heavy loads. Even the fleeting wind

FIG. 181. — Man's strength is not sufficient for heavy work.

has been harnessed by man, and, as in the windmill, made to work for him (Fig. 182). One sees dotting the country windmills large and small, and in Holland, the country of windmills, the landowner who does not possess a windmill is poor indeed.

For generations running water from rivers, streams, and falls has served man by carrying his logs downstream, by turning the wheels of his mill; and in our own day running water is used as an indirect source of electric lights for street and house.

A more constant source of energy is that available from the burning of fuel, such as coal and oil. The former is the source of energy in locomotives, the latter in most automobiles.

In the following chapter will be given an account of water,

FIG. 182. — The windmill pumps water into the troughs where cattle drink.

wind, and fuel as machine feeders.

CHAPTER XXXIII

THE POWER BEHIND THE ENGINE

SMALL boys soon learn the power of running water; swimming or rowing downstream is easy, while swimming or rowing against the current is difficult, and the swifter the water, the easier the one and the more difficult the other; the river assists or opposes us as we go with it or against it. The water of a quiet pool or of a gentle stream cannot do work, but water which is plunging over a precipice or a dam, or is flowing down steep slopes, may be made to saw wood, grind our corn, light our streets, or run our electric cars. A waterfall, or a rapid stream, is a great asset to any community, and for this reason should be carefully guarded. Water power is as great a source of wealth as a coal bed or a gold mine.

The most tremendous waterfall in our country is Niagara Falls, which every minute hurls millions of gallons of water down a 163-foot precipice. The energy possessed by such an enormous quantity of water flowing at such a tremendous speed is almost beyond everyday comprehension, and would suffice to run the engines of many cities far and near. Numerous attempts to buy from the United States the right to utilize large quantities of this apparently wasted energy have been made by various commercial companies. It is fortunate that these negotiations have been largely fruitless, because the deviation of large quantities of water for commercial uses and the installation of machinery in the vicinity of the famous falls would greatly detract from the beauty of this world-known scene, and would rob our country of a natural beauty unequalled elsewhere.

Water wheels. — In Figure 183 the water of a small but rapid mountain stream is made to rotate a large wheel, which in turn

communicates its motion through belts to a distant sawmill or grinder. In more level regions huge dams are built which hold back the water and keep it at a higher level than the wheel; from the dam the water is conveyed in pipes (flumes) to the paddle wheel which it turns. Cogwheels or belts connect the pad-

FIG. 183. — A mountain stream turns the wheels of the mill.

dle wheel with the factory machinery, so that motion of the paddle wheel insures the running of the machinery.

One of the most efficient forms of water wheels is that shown in Figure 184, and called the Pelton wheel. Water issues in a narrow jet similar to that of the ordinary garden hose and strikes with great force against the lower part of the wheel, thereby causing rotation of the wheel. Belts transfer this motion to the machinery of the factory or mill.

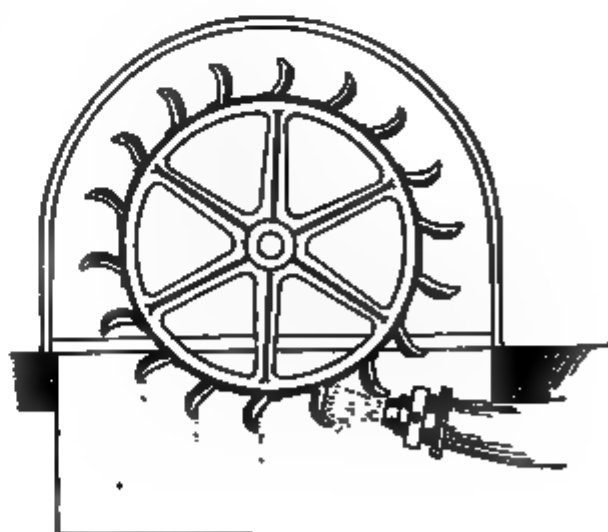


FIG. 184. — The Pelton water wheel.

Windmills. — Those of us who have spent our vacation days in the country know that there is no ready-made water

supply there as in the cities, but that as a rule the farmhouses obtain their drinking water from springs and wells. In poorer houses, water is laboriously carried in buckets from the spring or is lifted from the well by a windlass. In more prosperous houses, pumps are installed; this is an improvement over the original methods, but the quantity of water consumed by the average family is so great as to make the task of pumping an arduous one.

The average amount of water used per day by one person is 25 gallons. This includes water for drinking, cooking, dish washing, bathing, laundry. For a family of five, therefore, the daily consumption would be 125 gallons; if to this be added the water for a single horse, cow, and pig, the total amount needed will be approximately 150 gallons per day. A strong man can pump that amount from an ordinary well in about one hour, but if the well is deep, more time and strength are required.

The invention of the windmill was a great boon to country folks because it eliminated from their always busy life one task in which labor and time were consumed.

The principle of the windmill.

—The toy pin wheel is a windmill in miniature. The wind strikes the sails, and causes rotation; and the stronger the wind blows, the faster will the wheel rotate. In windmills, the sails are of wood or steel, instead of paper, but the principle is identical.

FIG. 185. —The toy pin wheel is a miniature windmill.

As the wheel rotates, its motion is communicated to a mechanical device which raises water as long as the wind continues to blow.

The water thus raised empties into a large tank, built either in the windmill tower or in the garret of the house, and from the tank the water flows through pipes to the different parts of the house. In very windy weather the wheel rotates rapidly, and the tank fills quickly. In order to guard against an overflow from the tank, a mechanical device is installed which stops

FIG. 186. — The windmill pumps water into the tank.

rotation of the wheel when the tank is nearly full. The tank is usually large enough to hold an amount of water sufficient for several days, and hence a continuous calm of a day or two does not materially affect the house supply. When once built, a windmill practically takes care of itself, except for oiling, and is an efficient and cheap domestic possession.

Steam as a working power. — If a delicate vane is held at an opening from which steam issues, the pressure of the steam will cause rotation of the vane (Fig. 187), and if the vane is

connected with a machine, work can be obtained from the steam.

When water is heated in an open vessel, the pressure of its steam is too low to be of practical value, but if on the contrary water is heated in an almost closed vessel, its steam pressure is considerable. If steam at high pressure is directed by noz-

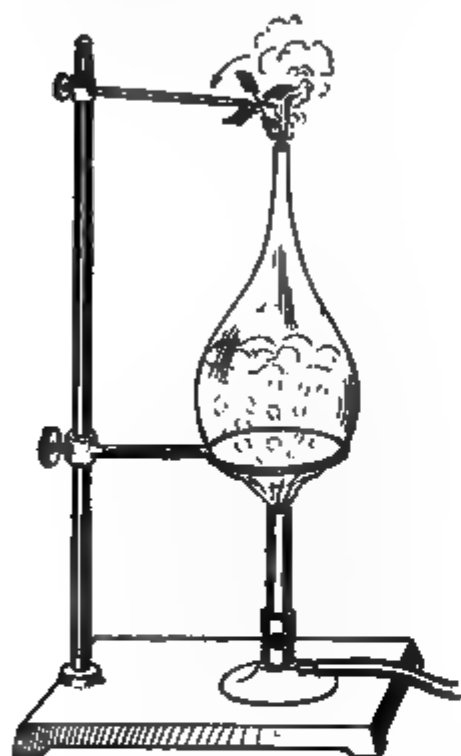


FIG. 187. — Steam as a source of power.

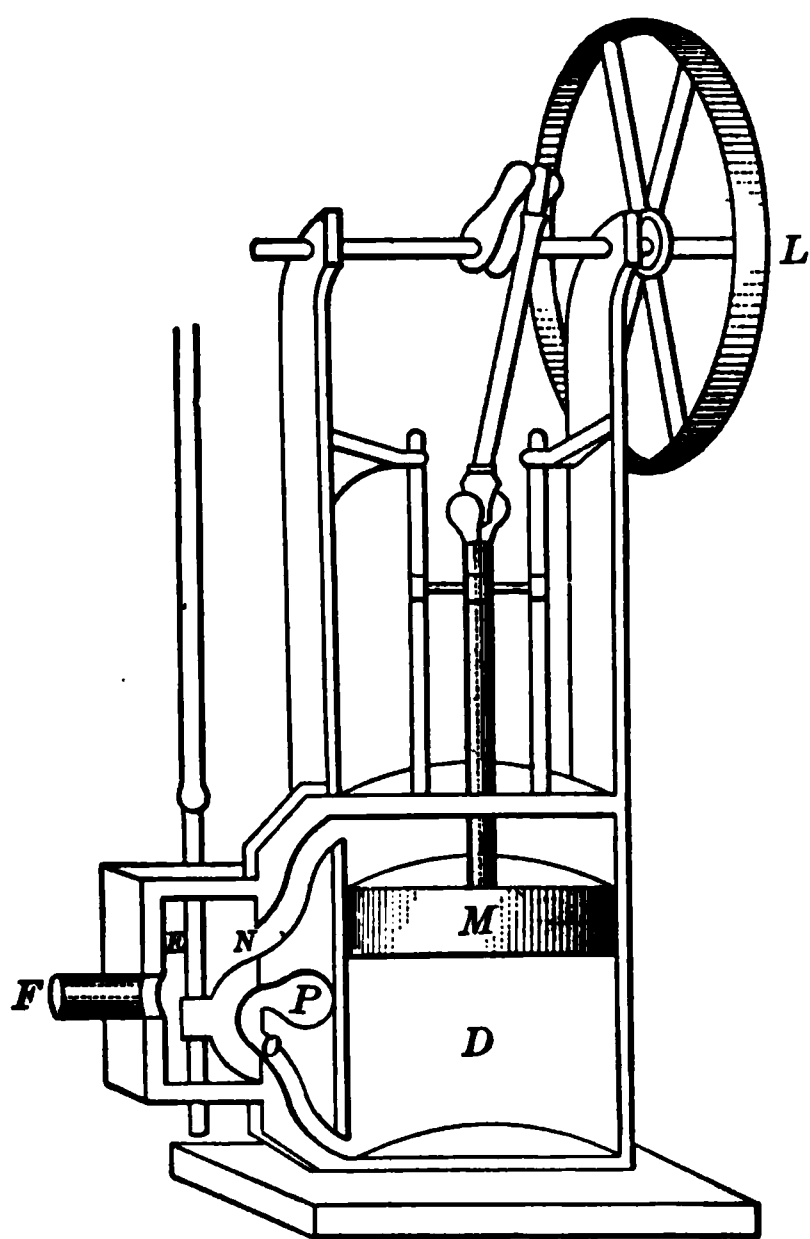
FIG. 188. — Steam turbine with many blades and 4 nozzles. (De Laval.)

zles against the blades of a wheel, rapid rotation of the wheel results just as it did in Figure 184, although in this case steam pressure replaces water pressure. After the steam has spent itself in turning the turbine, it condenses into water and makes its escape through openings in an inclosing case. In Figure 188 the protecting case is removed, in order that the form of the turbine and the positions of the nozzles may be visible.

A single large turbine wheel may have as many as 800,000 sails or blades, and steam may pour out upon these from many nozzles.

The steam turbine is very much more efficient than its forerunner, the steam engine. The installation of turbines on ocean liners has been accompanied by great increase in speed, and by an almost corresponding decrease in the cost of maintenance.

Steam engines. — A very simple illustration of the working of a steam engine is given in Figure 189. Steam under pressure



enters through the opening *F*, passes through *N*, and presses upon the piston *M*. As a result *M* moves downward, and thereby induces rotation in the large wheel *L*.

As *M* falls, it drives the air in *D* out through *O* and *P* (the opening *P* is not visible in the diagram).

As soon as this is accomplished, a mechanical device draws up the rod *E*, which in turn closes the opening *N*, and thus prevents the steam from passing into the part of *D* above *M*.

FIG. 189. — The principle of the steam engine.

But when the rod *E* is in such a position that *N* is closed, *O* on the other hand is open, and steam rushes through it into *D* and forces up the piston. This up-and-down motion of the piston causes continuous rotation of the wheel *L*. If the fire is hot, steam is formed quickly and the piston moves rapidly; if the fire is

low, steam is formed slowly and the piston moves less rapidly.

The steam engine as seen on our railroad trains is very complex and cannot be discussed here; in principle, however, it is identical with that just described. Figure 190 shows a steam harvester at work on a modern farm.

FIG. 190. — Steam harvester at work.

In both engine and turbine the real source of power is not the steam, but the fuel, such as coal or oil, which converts the water into steam.

Gas engines. — Automobiles have been largely responsible for the gas engine. To carry coal for fuel and water for steam would be impracticable for most motor cars. Electricity is used in some cars, but the batteries are heavy, expensive, and short-lived, and are not always easily replaceable. For this reason gasoline is extensively used, and in the average automobile the source of power is the force generated by exploding gases.

It was discovered some years ago that if the vapor of gasoline or naphtha was mixed with a definite quantity of air, and

a light was applied to the mixture, an explosion would result. Modern science uses the force of such exploding gases for the accomplishment of work, such as the running of automobiles and launches.

In connection with the gasoline supply is a carburetor or sprayer, from which the cylinder *C* (Fig 191) receives a fine mist of gasoline vapor and air. This mixture is ignited by an

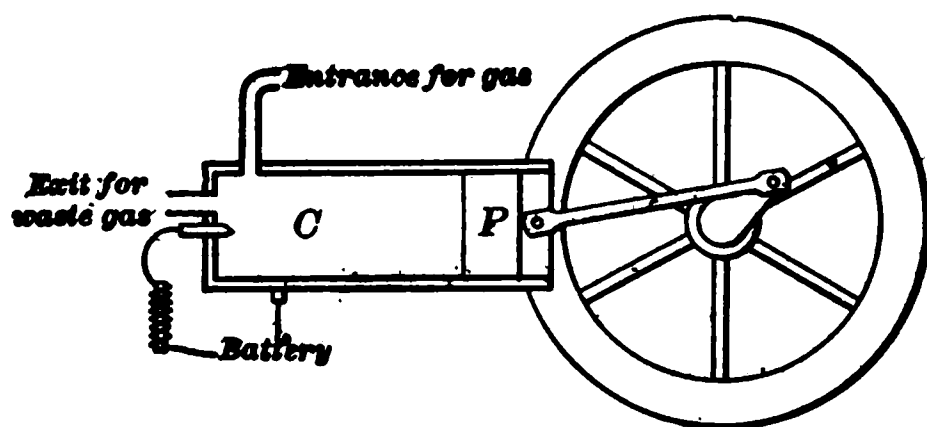


FIG. 191. — The gas engine.

automatic, electric sparking device and the explosion of the gases drives the piston *P* to the right. In the 4-cycle type of gas engines (Fig. 191) —the kind used in automobiles—the

four strokes are as follows: 1. The mixture of gasoline and air enters the cylinder as the piston moves to the right. 2. The valves being closed, the mixture is compressed as the piston moves to the left. 3. The electric spark ignites the compressed mixture and drives the piston to the right. 4. The waste gas is expelled as the piston moves to the left. The exhaust valve is then closed, the inlet valve opened, and another cycle of four strokes begins.

The use of gasoline in launches and automobiles is familiar to many. Not only are launches and automobiles making use of gas power, but the gasoline engine has made it possible to propel aëroplanes through the air.

CHAPTER XXXIV

PUMPS, AND THEIR VALUE TO MAN

“As difficult as for water to run up a hill!” Is there any one who has not heard this saying? Yet most of us accept as a matter of course the stream which gushes from our faucet, or give no thought to the ingenuity which devised a means of forcing water upward through pipes. Despite the fact that water flows naturally down hill, and not up, we find it available in our homes and office buildings, in some of which it ascends to the fiftieth floor; and we see great streams of it directed upon the tops of burning buildings by firemen in the streets below.

In the country, where there are no great central pumping stations, water for the daily need must be raised from wells, and the supply of each household is dependent upon the labor and foresight of its members. The water may be brought to the surface either by laboriously raising it, bucket by bucket, or by the less arduous method of pumping. These are the only means possible; even the windmill does not eliminate the necessity for the pump, but merely replaces the energy used by man in working it.

In some parts of our country we have oil beds or wells. But before this underground oil can be of service to man, it must be brought to the surface, and this is accomplished, as in the case of water, by the use of pumps.

An old tin can or a sponge may serve to bale out water from a leaking rowboat, but such a crude device would be absurd if employed on our huge vessels of war and commerce. A rent in the ship's side would mean inevitable loss, were

it not possible to rid the ship of the inflowing water by strong pumps.

Another and very different use to which pumps are put is seen in the compression of gases. Air is forced into the tires of bicycles and automobiles until they become sufficiently inflated to insure comfort in riding. Some present-day sys-

tems of artificial refrigeration could not exist without the aid of compressed gases.

Compressed air has played a very important rôle in mining, being sent into poorly ventilated mines to improve the condition of the air, and to supply to the miners the oxygen necessary for respiration. Divers

FIG 102. - Carrying water home from the spring.

and men who work

under water carry on their backs a tank of compressed air, and take from it the amount required.

There are many forms of pumps. They serve widely different purposes and are essential to the operation of many industrial undertakings.

The air as man's servant. — Long before man harnessed water for turbines, or steam for engines, he made the air serve his purpose, and by means of it raised water from hidden underground depths to the surface of the earth; likewise, by means of it, he raised to his dwelling on the hillside water from the stream in the valley below. Those who live in cities where running water is always present in the home cannot

realize the hardship of the days when this “ready-made” supply did not exist, but when man laboriously carried to his dwelling, from distant spring and stream, the water necessary for the daily need (Fig. 192).

What are the characteristics of the air which have enabled man to accomplish these feats? They may be briefly stated as follows: —

(1) Air has weight. One cubic foot of air, at atmospheric pressure, weighs $1\frac{1}{2}$ ounces. (See Chapter XXXVIII.)

(2) The air around us presses with a force of about 15 pounds upon every square inch of surface that it touches.

(3) Air is elastic. It can be compressed, as in the balloon or bicycle tire, but it expands immediately when pressure is reduced. As it expands and occupies more space, its pressure falls and it exerts less force against the matter with which it comes in contact. If, for example, one cubic foot of air is allowed to expand and occupy two cubic feet of space, its pressure is reduced one half. When air is compressed, its pressure increases and it exerts a greater force against the matter with which it comes in contact. If two cubic feet of air are compressed to one cubic foot, the pressure of the compressed air is doubled.

The common pump or lifting pump. — Place a tube containing a close-fitting piston in a vessel of water, as shown in Figure 193. Then raise the piston with the hand and notice that the water rises in the piston tube. The atmosphere presses with a force of 15 pounds upon every square inch of water in the large vessel and forces some of it into the space left vacant by the retreating piston. The common pump works in a similar

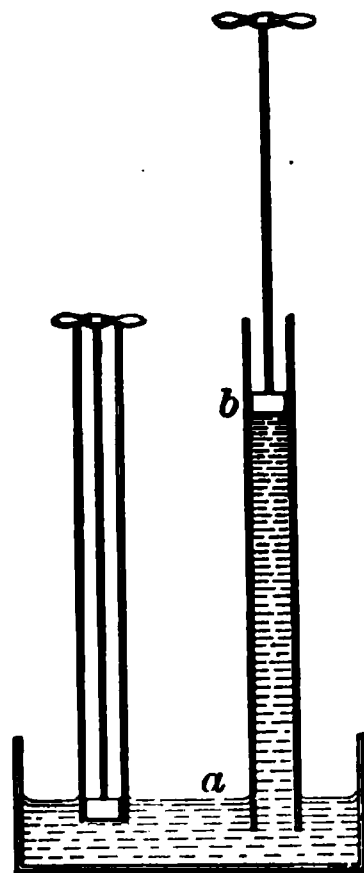


FIG. 193. — The atmosphere pressing downward on *a* pushes water after the rising piston *b*.

manner. It consists of a piston or plunger which moves back and forth in an air-tight cylinder, and which contains an outward-opening valve through which water and air can pass. From the bottom of the cylinder a tube runs down into the well or reservoir, and water from the well has access to the cylinder through another outward-moving valve. In practice the tube is known as the suction pipe, and its valve as the suction valve.

In order to understand the action of a pump, we will suppose that no water is in the pump, and we will pump until a stream issues from the spout. The various stages are represented diagrammatically by Figure 194. In (1) the entire pump is empty of water but full of air at atmospheric pressure, and both valves are closed. In (2) the plunger is being raised and is lifting the column of air that rests on it. The air and water in the inlet pipe, being thus partially relieved of downward pressure, are pushed up by the atmospheric pressure on the surface of the water in the well. When the piston moves downward, as in (3), the valve in the pipe closes by its own weight, and the air in the cylinder escapes through the valve in the plunger. In (4) the piston is again rising, repeating the process of (2). In (5) the process of (3) is being repeated, but water instead of air is escaping through the valve in the plunger. In (6) the process of (2) is being repeated, but the water has reached the spout and is flowing out.

After the pump is in position (6), motion of the plunger is followed by a more or less regular discharge of water through the spout. The quantity of water which gushes forth depends upon the speed with which the piston is moved. A strong man giving quick strokes can produce a large flow; a child, on the other hand, is able to produce only a thin stream. Whoever pumps must exert sufficient force to lift the water from the surface of the well to the spout exit. For this reason the pump has received the name of *lifting pump*.

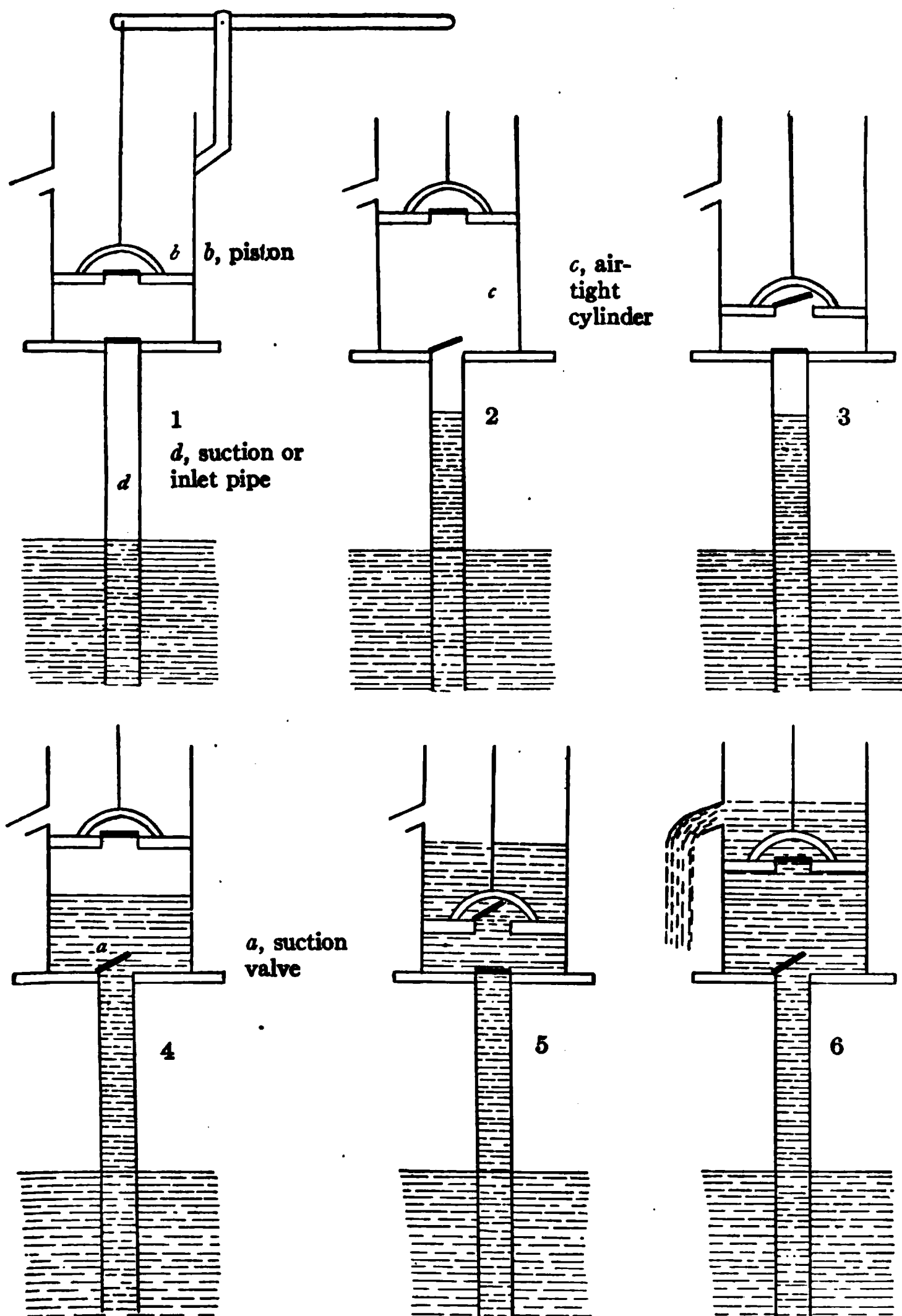


FIG. 194. — Diagram of the process of pumping.

In the common pump, water cannot be raised higher than 34 feet. (See Chapter XXXVIII.) In many cases it is desirable to force water considerably higher, as, for instance, in the fire hose. Under such circumstances a type of pump is employed which has received the name of *force pump*. In the force pump valves are placed in the cylinder, and the piston is solid, but the principle is the same as in the lifting pump.

FIG. 105. — Agriculture made possible by irrigation

Irrigation and drainage. — For many present-day enterprises force pumps and lift pumps are inconvenient and impracticable, and they have been replaced in many cases by more modern types, such as the rotary and centrifugal pumps. In these pumps, rapidly rotating wheels lift the water and drive it onward into a discharge pipe, from which it issues with great force. There is neither piston nor valve, and the quantity of water raised and the force with which it is driven through the pipes depend solely upon the size of the wheels and the speed with which they rotate.

Irrigation, or the artificial watering of land, is of great importance in those parts of the world where the land is naturally too dry for farming. In the United States, approximately two fifths of the land is so dry that it is worthless for agricultural purposes unless artificially watered. In the West, several large

irrigating systems have been built by the federal government, and about ten million acres of land have been converted by irrigation from worthless farms into fields rich in crops (Fig. 195). Most irrigating systems use centrifugal pumps to force water over long distances and to supply it in quantities sufficient for vast agricultural needs. In many regions, the success of a farm or a ranch depends upon the irrigation furnished in dry seasons, or upon man's ability to pump water from a region of abundance to a remote region of scarcity (Fig. 196).

FIG. 196. — Rice for its growth needs periodical flooding, and irrigation often supplies the necessary water.

The draining of land is also a matter of importance. Swamps and marshes which were at one time considered useless have been drained and thus reclaimed and converted into good farming land. The surplus water is removed from the soil by centrifugal pumps. Sand and sticks which are in the water would clog the valves of an ordinary pump but are passed along without difficulty by the rotating wheel.

Camping. Its pleasures and its dangers. — The allurements of a vacation camp in the heart of the woods is so great as to make many campers ignore the vital importance of securing a safe water supply. A river bank may be beautiful and teeming with diversions, but if the river is used as a source of drinking water it will usually prove fatal to some. The impure water can be boiled, it is true, but few campers are willing to forage for the additional wood needed for this apparently unnecessary requirement; then, too, boiled water does not cool readily in summer and is disagreeable for drinking purposes.

The only safe course is to abandon the river as a source of drinking water, and if a spring cannot be found, to drive a well. In many regions, especially in the neighborhood of streams, water can be found ten or fifteen feet below the surface. Water taken from such a depth has filtered through a bed of soil, and is fairly safe for any purpose. Of course the deeper the well, the safer is the water.

With the use of a good pump, campers can, without grave danger, throw dish water, etc., on the ground somewhat remote from the camp. This will not injure their drinking water because the liquids will slowly seep through the ground, and as they filter downward will lose their dangerous matter. All the water which reaches the well will have filtered through the soil bed and will probably be safe.

While the careless disposal of wastes may not spoil the drinking water (in the well to be described), other laws of health demand a thoughtful disposal of wastes. The malarial mosquito and the typhoid fly flourish in unhygienic quarters, and the only way to guard against their dangers is to allow them neither food nor breeding place.

The burning of garbage, the discharge of waters into cesspools, or, in temporary camps, the discharge of wastes to distant points, through a cheap sewage pipe insures safety to

campers, lessens the trials of flies and mosquitoes, and adds but little to the expense.

A cheap well for campers.—A two-inch galvanized iron pipe with a strong, pointed end containing small perforations is driven into the ground with a sledge hammer. After it has penetrated for a few feet, another length is added and the whole is driven down. This is repeated until water is reached. A cheap pump is then attached to the upper end of the drill pipe and serves to raise the water. During the drilling, some soil particles get into the pipe through the perforations and cloud the water at first; but after the pipe has once been cleaned by the upward-moving water, the supply remains clear. The flow from such a well is naturally small; first, because water is not abundant near the surface of the earth, and, second, because cheap pumps are poorly constructed and cannot raise a large amount. But the supply is usually sufficient for the needs of simple camp life, and many a small farm uses such a well, not only for household purposes, but for watering the cattle in winter (Fig. 197).

FIG. 197. — A driven well.

If the cheapness of such pumps were known, their use would be more general for temporary purposes. The cost of material need not exceed \$5 for a 10-foot well, and the driving of the pipe could be made as much a part of the camping as the pitching of the tent itself. If the camping site is abandoned at the

close of the vacation, the pump can be removed and kept over winter for use the following summer in another place. In this way the actual cost of the water supply can be reduced to scarcely more than \$3, the removable pump being a permanent

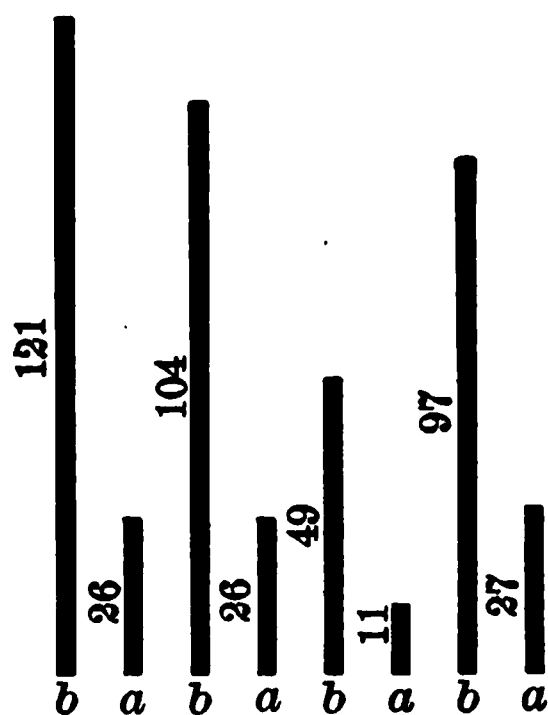


FIG. 198. — Diagram showing how supplying a city with good water lessens sickness and death. The lines *b* show the relative number of people who died of typhoid fever before the water was filtered; the lines *a* show the numbers who died after the water was filtered. The figures are the number of typhoid deaths occurring yearly out of 100,000 inhabitants.

possession. In rocky or mountain regions the driven well is not practicable, because the driving point is blunted and broken by the rock and cannot pierce the rocky beds of land.

Our summer vacation.— It has been asserted by some city health officials that many cases of typhoid fever in cities can be traced to the unsanitary conditions existing in summer resorts. The drinking water of most cities is now under strict supervision, while that of isolated farms, of small seaside resorts, and of scattered mountain hotels is left to the care of individual proprietors, and in only too many instances receives no attention whatever. The sewage disposal is often inadequate and badly planned, and the water becomes dangerously contaminated.

A strong, healthy person, with plenty of outdoor exercise and with hygienic habits, may be able to resist the disease germs present in the poor water supply. More often the summer guests carry back with them to their winter homes the germs of disease, which gain the upper hand under the altered conditions of city and business life. It is not too much to say that every man and woman should know the source of his summer table water and the method of sewage disposal. If the con-

ditions are unsanitary, they cannot be remedied at once, but another resort can be found and personal danger can be avoided. Public sentiment and the loss of trade will go far in furthering an effort toward better sanitation.

In the driven well, water cannot reach the spout unless it has first filtered through the soil to the depth of the driven pipe. After such a journey it is fairly safe, unless very large quantities of sewage are present.

Abundant water is rarely reached at less than 75 feet, and it would usually be impossible to drive a pipe to such a depth. When a large quantity of water is desired, strong machines drill into the ground and excavate an opening into which a wide pipe can be lowered. Recently in the Pocono Mountains I saw such a well completed. The machine drilled to a depth of 250 feet before much water was reached and to over 300 feet before a flow was obtained sufficient to satisfy the owner. The water thus obtained was the sole water supply of a hotel accommodating 150 persons. The proprietor calculated that the requirements of his guests, for bath, toilet, laundry, and kitchen, and of the domestics employed to serve



FIG. 199. — A deep well with the piston in the water.

them, together with the livery, demanded a flow of 10 gallons per minute. The ground was full of rock and difficult to penetrate, and it required 6 weeks of constant work for two skilled men to drill the opening, lower the suction pipe, and install the pump, the cost being approximately \$700.

The water from such a well is safe and pure except under the conditions represented in Figure 72. If sewage or slops are poured upon the ground in the neighborhood of the well, the liquid will seep through the ground and some may make its way into the pump before it has been purified by the earth. The impure liquid thus contaminates the otherwise pure water and renders it decidedly harmful. For absolute safety the sewage discharge should be at least 75 feet from the well. In large hotels, where there is necessarily a large quantity of sewage, the distance should be much greater. As the sewage seeps through the ground it loses its impurities, but the quantity of earth required to purify it depends upon its abundance; a small depth of soil cannot take care of an indefinite amount of sewage. Hence, the greater the number of people in a hotel, or the more abundant the sewage, the greater should be the distance between well and sewer.

By far the best way to avoid contamination is to see to it that the sewage discharges into the ground *below* the well; that is, to dig the well in such a location that the sewage drains away from the well.

Pumps which compress air. — The pumps just considered have their widest application in agricultural districts. From a commercial and industrial standpoint a most important class of pump is that known as the compression type. In these, air or any other gas is compressed rather than rarefied.

Air brakes and self-opening and self-closing doors on cars are operated by means of compression pumps. The laying of bridge and pier foundations, in fact all work which must

be done under water, is possible only through the use of compression pumps. Those who have visited mines, and have gone into the heart of the underground labyrinth, know how difficult it is for fresh air to make its way to the miners. Compression pumps have eliminated this difficulty, and to-day fresh air is constantly pumped into the mines to supply the laborers there.

FIG. 200. — Spraying trees by means of a compression pump.

Agricultural methods also have been modified by the compression pump. The spraying of trees formerly done slowly and laboriously, is now done very simply by pumps (Fig. 200).

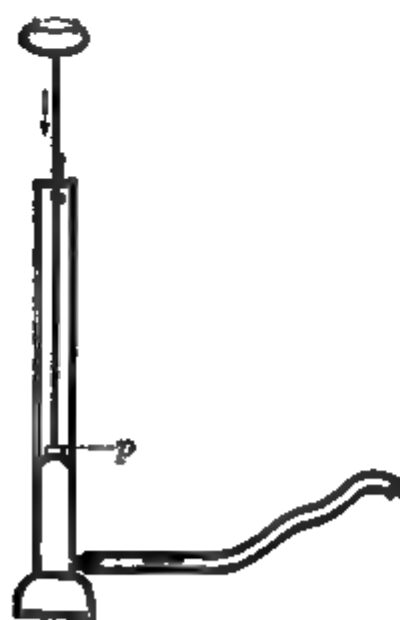


FIG. 201. — The bicycle foot pump.

The bicycle pump. — The bicycle pump is the best known of all compression pumps. Here, as in all compression pumps, the valves open inward rather than outward. When the piston (*p*) is lowered, compressed air is driven through the rubber tubing, pushes open an inward-opening valve in the tire, and enters the tire. When the piston is raised, the lower valve closes, the upper valve is opened by atmospheric pressure, and air from outside

enters the cylinder. The next stroke of the piston drives a fresh supply of air into the tire, which thus in time becomes inflated. In most cheap bicycle pumps, the piston valve is replaced by a soft piece of leather so attached to the piston that it allows air to flow into the cylinder, but prevents its escape from the cylinder (Fig. 201).



FIG. 202. — Water does not enter the tube as long as we blow into it.

How a man works under water.— Place one end of a piece of glass tube in a vessel of water and notice that the water rises in the tube. Blow into the tube and see whether you can force the water down the tube (Fig. 202). If the tube is connected to a small compression pump, sufficient air can be sent into the tube to cause the water to sink

and to keep the tube permanently clear of water. This is, in brief, the principle employed for work under water. A compression pump forces air through a tube into the chamber in which men are to work (Fig. 203). The air thus furnished from above supplies the workmen with oxygen, and by its pressure prevents water from entering the chamber. When the task has been completed, the chamber is raised and later lowered to a new position.

FIG. 203 — The principle of work under water.

Combination of pumps.— In many cases the combined use of both exhaust and compression pumps is necessary to secure

the desired result; as, for example, in pneumatic dispatch tubes seen in department stores. These are employed in the transportation of letters and small packages from building to building or between parts of the same building. A pump removes air from the part of the tube ahead of the package and reduces the resistance, while a compression pump forces air into the tube behind the package and drives it forward with great speed.

CHAPTER XXXV

THE WATER PROBLEM OF A LARGE CITY

It is by no means unusual for the residents of a large city or town to receive through the newspapers a notification that the city water supply is running low and that economy should be exercised in its use. The problem of supplying a large city with an abundance of pure water is among the most difficult tasks which city officials have to perform, and is little understood or appreciated by the average citizen.

Intense interest in personal and domestic affairs is natural, but every citizen, rich or poor, should have an interest in civic affairs as well, and there is no better or more important place to begin than with the water supply.

Where does your city obtain its water? Does it bring water to its reservoirs in the most economic way possible, and is there any legitimate excuse for the scarcity of water which many communities face in dry seasons?

Two possibilities. — Sometimes a city is fortunate enough to be situated near hills and mountains through which streams flow, and in that case the water problem is simple. All that is necessary is to run pipes, usually underground, from the elevated lakes or streams to individual houses, or to common reservoirs from which it may be distributed to the various buildings.

Figure 204 illustrates in a simple way how a mountain lake may supply the inhabitants of a valley. Such a system of water distribution is known as the gravity system. The nearer

FIG. 204. — The elevated mountain lake serves as a source of water.

and steeper the elevation, the greater the force with which the water flows through the valley pipes, and the stronger the discharge from the faucets.

Relatively few cities and towns are so favorably situated as regards water. More often the mountains are too distant, or the elevation is too slight, to be of practical value. Cities situated in plains and remote from mountains are obliged to utilize the streams that flow through the land, forcing the water to the necessary height by means of pumps. Streams that flow through populated regions are apt to be contaminated, and water from them requires public filtration. Cities using such a water supply thus have the double expense of pumping and of filtration.

The pressure of water. — No practical business man would erect a turbine or paddle wheel without calculating in advance the value of his water power. The paddle wheel might be so heavy that the stream could not turn it, or so frail in comparison with the water force that the stream would destroy it. In just as careful a manner, the size and the strength of municipal reservoirs and pumps must be calculated. The greater the quantity of water to be held in the reservoir, the heavier are

the walls required. The greater the elevation of the houses, the stronger must be the pumps and the engines which run them.

In order to understand how these calculations are made, we must learn about the pressure of water.

One cubic foot of it weighs about 62.5 pounds; this is equivalent to saying that water 1 foot deep presses on the bottom of the containing vessel with a force of 62.5 pounds to the square foot. If the water is 2 feet deep, the load supported by the vessel is doubled, and the pressure on each square foot of the bottom of the vessel will be 125 pounds, and if the water is 10 feet deep, the load borne by each square foot will be 625 pounds. The deeper the water, the greater is the weight sustained by the confining vessel and the greater the pressure exerted by the water.

FIG. 205.—Water 1 foot deep exerts a pressure of 62.5 pounds a square foot.

Since the pressure borne by 1 square foot of surface is 62.5 pounds, the pressure supported by 1 square inch of surface is $\frac{1}{144}$ of 62.5 pounds, or .43 pound, nearly $\frac{1}{2}$ pound. Suppose a vessel held water to the depth of 10 feet, then upon every square inch of the bottom of that vessel there would be a pressure of 4.34 pounds. If a one-inch tap were inserted in the bottom of the vessel so that the water flowed out, it would gush forth with a force of 4.34 pounds. If the water were 20 feet deep, the force of the outflowing water would be twice as strong, because the pressure would be doubled. But the flow would not remain constant. As the water leaves the outlet, less and less of it remains in the

vessel, the pressure gradually sinks, and the flow drops correspondingly.

In seasons of prolonged drought, the streams which feed a city reservoir are apt to contain less than the usual amount of water, hence the level of the water supply sinks, the pressure at the outlet falls, and the force of the outflowing water is lessened.

Why the water supply is not uniform in all parts of the city. — In the preceding section, we saw that the flow from a faucet depends upon the height of the reserve water above the tap. Houses on a level with the main supply pipes (Figs. 204 and 206) have a strong flow, because the water is under the pressure of a column *A*; houses situated on elevation *B* have less flow,

FIG. 206. — Water pressure varies in different parts of a water system.

because the water is under the pressure of a shorter column *B*; and houses at a considerable elevation *C* have a less rapid flow corresponding to the diminished depth (*C*).

Not only does the flow vary with the elevation of the house, but it varies with the location of the faucet within the house. Unless the reservoir is very high, or the pumps very powerful, the flow on the upper floors is noticeably less than that in the cellar, and in the upper stories of some high buildings the flow is scarcely more than a feeble trickle.

During a long journey, considerable force is expended against friction, and the flow at a distance from the reservoir falls to but a fraction of its original strength. For this reason,

buildings situated near the main supply have a much stronger flow (Fig. 207) than those on the same level but remote from the supply. Artificial reservoirs and standpipes are usually constructed on the near outskirts of a town in order that the

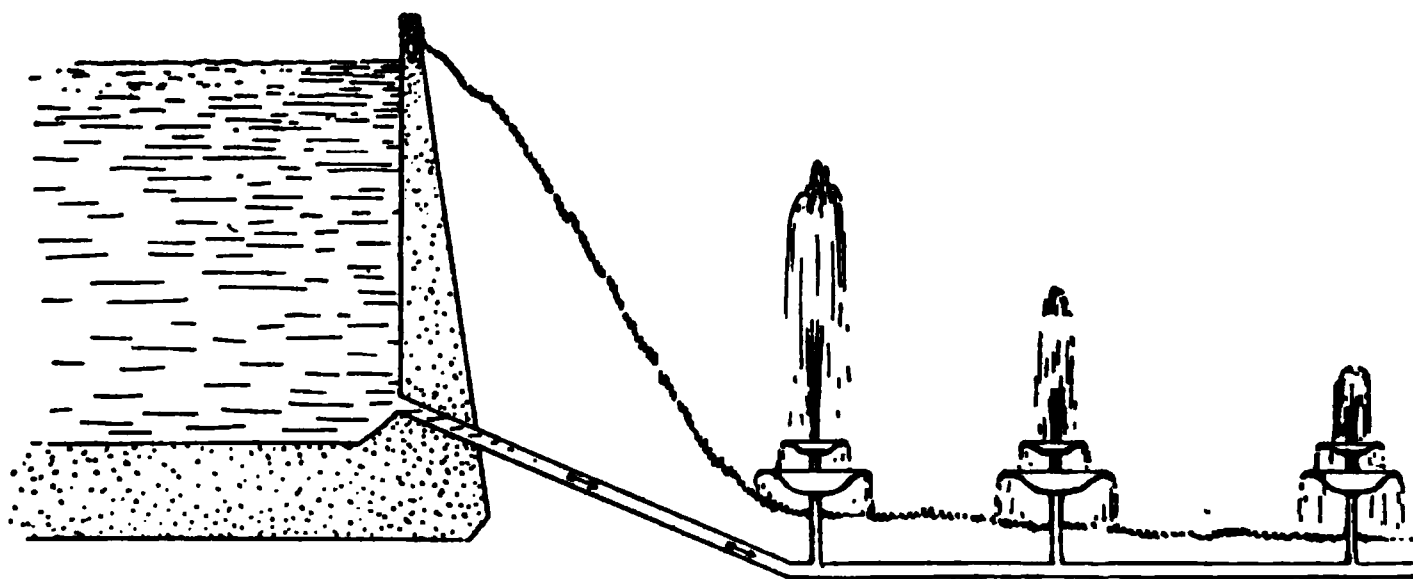


FIG. 207. — The more distant the fountain, the weaker the flow.

frictional force lost in transmission may be reduced to a minimum.

Why water does not always flow from a faucet. — Most of us have at times been annoyed by the inability to secure water on an upper story, because of the drawing off of water on a lower floor. During the working hours of the day, immense quantities of water are drawn off from innumerable faucets, and the pressure in the pipes decreases considerably. Buildings at a distance from the reservoir suffer under such circumstances, because while the diminished pressure is ordinarily powerful enough to supply the lower floors, it is frequently too weak to force a continuous stream to high levels. At night, however, and out of working hours, few faucets are open, less water is drawn off at any one time, and the pipes are constantly full of water under high pressure. At such times, a good flow is obtainable even on the uppermost floors.

The cost of water. — In the gravity system, where an ele-

vated lake or stream serves as a natural reservoir, the cost of the city's waterworks is practically limited to the laying of pipes. But when the source of the supply is more or less on a level with the surrounding land, the cost is great, because the supply for the entire city must either be pumped into an artificial reservoir, from which it can be distributed, or else must be driven directly through the mains (Fig. 208).

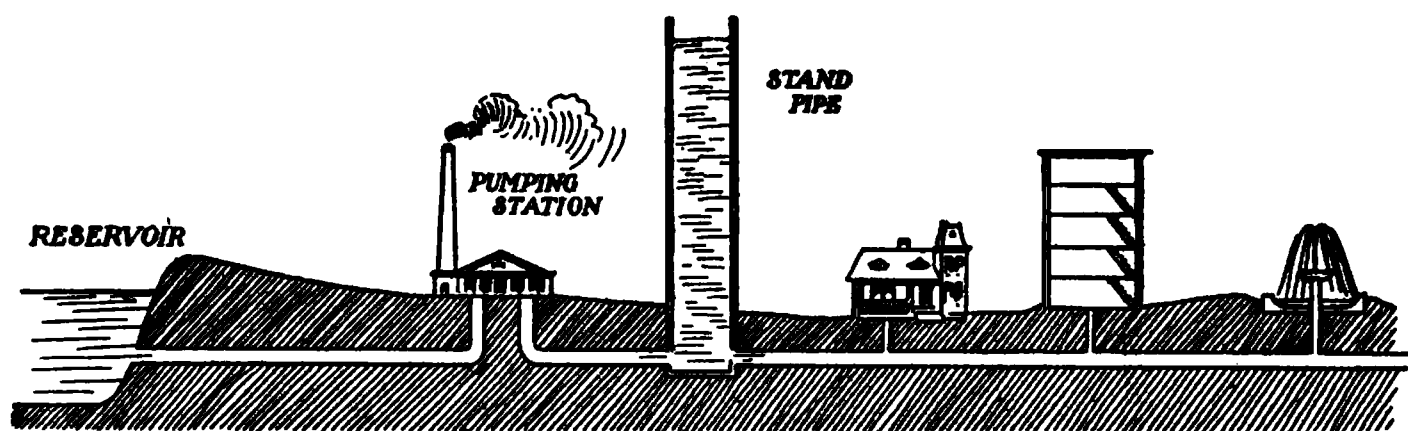


FIG. 208. — Water must be got to the houses by means of pumps.

A gallon of water weighs approximately 8.3 pounds, and hence the work done by a pump in raising a gallon of water to the top of an average house, an elevation of 50 feet, is 8.3×50 , or 415 foot pounds. A small manufacturing town uses at least 1,000,000 gallons daily, and the work done by a pump in raising that amount to an elevation of 50 feet would be $8.3 \times 1,000,000 \times 50$, or 415,000,000 foot pounds.

The total work done during the day by the pump, or the engine driving the pump, is 415,000,000 foot pounds, and hence the work done during one hour would be $\frac{1}{24}$ of 415,000,000, or 17,291,666 foot pounds; the work done in one minute would be $\frac{1}{60}$ of 17,291,666, or 288,194 foot pounds, and the work done each second would be $\frac{1}{60}$ of 288,194, or 4803 foot pounds.

A 1-H.P. engine does 550 foot pounds of work each second, and therefore if the pump is to be operated by an engine, the strength of the latter would have to be 8.7 H.P. An 8.7-H.P.

pumping engine working at full speed every second of the day and night would be able to supply the town with the necessary amount of water. When, however, we consider the actual height to which the water is raised above the pumping station, and the extra pumping which must be done in order to balance the frictional loss, it is easy to understand that in actual practice a much more powerful engine would be needed.

In many large cities there is no one single pumping station which supplies all parts of the city, but several pumping stations are scattered throughout the municipality, each of which supplies a restricted territory.

Water and its dangers. — We need an abundance of pure drinking water, but the water of lakes and streams is seldom pure. This is because running water picks up animal and vegetable matter and carries it along in solution and suspension. The power of water to gather up matter is so great that the average drinking water contains 20 to 90 grains of solid matter per gallon; that is, if a gallon of ordinary drinking water is left to evaporate, a residue of 20 to 90 grains will be left. As water runs down a slope it carries with it the filth gathered from acres of land, carries with it the refuse of stable, barn, and kitchen.

Too often this impure water finds its way into the streams that supply our cities (Fig. 209). One winter in Plymouth, Pa., excreta from a typhoid patient was thrown on a snow-bank. With the first warm days of spring, the snow melted and ran down into one of the city's reservoirs, carrying with it excreta on which typhoid germs were living. Within a few weeks over 1000 of the citizens who used this reservoir were ill with typhoid fever.

All lakes and rivers which furnish drinking water should be carefully protected from surface drainage: that is, from water which has flowed over the land and has accumulated

FIG. 209. - As water flows over the land, it gathers filth and disease germs.

waste matter. More than three fourths of all cases of typhoid fever in the United States are caused by drinking water containing typhoid germs, and many stomach and bowel troubles are traced to contaminated water.

It is not necessary that water should be free from all foreign substances in order to be safe for drinking; a limited amount of mineral matter is not injurious and may sometimes be really beneficial. It is organic waste matter that causes trouble, because it usually contains large numbers of disease germs.

How water can be purified. — (a) Disease germs are destroyed by strong heat, and water that has been boiled for 15 or 20 minutes is safe to drink. Boiling is the most practical method of purification for the home. The boiled water should be put into clean bottles and kept corked. The taste of boiled

water is not as pleasant as that of raw or uncooked water, because the gases which give taste to raw water are expelled by boiling.

We know that fresh water contains dissolved gases because if a tumbler of water freshly drawn from the faucet is left on the table for a few minutes, gas bubbles collect on the sides of the tumbler. Warm water does not dissolve or hold in solution as much gas as cold water; and water loses air in the process of boiling. Although boiled water can never be as tasty as ordinary water, it can be improved by slowly pouring it from one vessel to another and allowing it to dissolve air from its surroundings.

(b) Water is purified by filtration; that is, by passage through porcelain or other porous substances which allow the passage of water, but hold back foreign particles suspended in it. The filters used in ordinary dwellings are of sand, asbestos, or charcoal; but they are often

worse than useless because they soon become choked and cannot be properly cleaned. Since the health of a community depends on its drinking water, it is the business of the city to provide good water and

FIG. 210. — Filtration.

most cities filter the water before it is sent to the residents. This is usually done by flowing the water over sand and gravel beds. The principle of filtration is shown in Figure 210. When impure water is poured into the tank, it seeps slowly through the layers of soil and issues from the bottom free from foreign particles. In the filtration plants owned and operated by large cities, water from rivers or lakes passes over

filter beds of coarse gravel and by seepage through them loses most of the larger particles suspended in it. It then passes through beds of fine sand and gravel and emerges from the last bed clear and pure. The separate filtration beds are often an acre in area and 5 or 6 feet deep. Filtration beds soon become choked with impurities and require frequent cleaning. When the beds are to be cleaned, the openings to the city outlet pipes are closed and water from a hose is directed against the sand. This stirs up the mud and washes the impurities to the top; there they drain off into sewage pipes through openings made for the purpose. If continued use of a powerful hose for several hours does not clean the soil, fresh soil is substituted.

The purification of water by filtration is due largely to beneficial bacteria which develop in the sand of the filter. Newly built filters or freshly cleaned filters do not satisfactorily purify the contaminated water which flows through them. Why not? Because soil bacteria have not had time to develop in them. But a scum of gelatin-like matter slowly forms on the upper surfaces and clings to the sand grains. This slimy covering is the product of living active bacteria in the soil. After sufficient of it has formed, the bacteria present in the water are entrapped in it and prevented from passing through the filter. The outflowing water is then satisfactorily purified or filtered. Bacteriologists make frequent daily tests of the water coming from filter beds and do not allow it to pass into the local supply tanks unless it is reasonably free of bacteria. Usually several days are required for the growth of the bacterial scum and for satisfactory working of the filter beds.

Bubbling fountain. — Many disease germs are spread from person to person through carelessness. When a person with diphtheria or tuberculosis drinks from a cup, he leaves germs on it that act as a source of disease to the next person who uses the cup. Every community should demand bubbling

fountains for schools, railroad stations, and shops (Fig. 211). Bubbling fountains are sanitary because the flowing water

washes away germs left by one person and keeps the fountain clean for the next drinker. Many states have required the railroads to abolish the common drinking cup and to substitute sanitary paper cups.

The composition of water. — Water was long thought to be a simple substance, but toward the end of the eighteenth century it was found to consist of two quite different substances, oxygen (O) and hydrogen (H).

FIG. 211. — A sanitary drinking fountain.

In order to prove this, send an electric current through water. Tip the ends of the wires which dip into the water with platinum and pour a little acid into the water. The acid facilitates chemical action very much as oil on machinery facilitates motion. As soon as the current begins to flow bubbles of gas rise from the end of the wire by which the current enters the water, and other bubbles of gas rise from the end of the wire by which the current leaves the water. These gases have come from the water and are the substances of which it is composed. If we place over each end of the wire an inverted jar filled with water, the gases are easily collected (Fig. 212). The first thing

we notice is that there is always twice as much of one gas as the other; that is, water is composed of two substances, one of which is always present in twice as large quantities as the other.

Hydrogen, a component of water. — On testing the gases into which water is broken up by an electric current, we find them to be quite different. The gas present in the smaller quantity is oxygen, a

FIG. 212. — The decomposition of water.

substance with which we are already familiar. The other gas, hydrogen, is new to us and is interesting as being the lightest known substance. An important fact about hydrogen is that in burning it gives about as much heat as five times its weight in coal. Its flame is blue and almost invisible by daylight, but intensely hot. If platinum wire is placed in an ordinary gas flame, it does not melt, but if placed in a flame of burning hydrogen, it melts very quickly.

The relation of forests to the water supply. — When heavy rains fall on a bare slope, or when snow melts on a barren hillside, a small amount of the water sinks into the ground, but by far the greater part of it runs off quickly and swells brooks and streams, thus causing floods and freshets.

When, however, rain falls on a wooded slope, the action is reversed; a small portion runs off, while the greater portion sinks into the soft earth. This is due partly to the fact that the roots of trees by their constant growth keep the soil loose and open, and form channels, as it were, along which the water can easily run. It is due also to the presence on the ground of

decaying leaves and twigs, or humus. The decaying vegetable matter which covers the forest floor acts more or less as a sponge, and quickly absorbs falling rain and melting snow. The water which thus passes into the humus and the soil beneath does not remain there, but slowly seeps downward, and finally after weeks and months emerges at a lower level as a stream. Brooks and springs formed in this way are constant feeders of rivers and lakes.

In regions where the land has been deforested, the rivers run low in season of prolonged drought, because the water which should have slowly seeped through the soil, and then supplied the rivers for weeks and months, ran off from the barren slopes in a few days.

Forests not only lessen the danger of floods, but they help to conserve our waterways, preventing a dangerous high-water mark in the season of heavy rains and melting snows, and preventing a shrinkage in dry seasons when the only feeders of the rivers are the underground sources. In the summer of 1911, during a prolonged drought in North Carolina, the city of Charlotte was reduced for a time to a practically empty reservoir; washing and bathing were eliminated, and machinery dependent upon water power and steam stood idle. Thousands of gallons of water were brought in tanks from neighboring cities, and emptied into the reservoir from whence it trickled slowly through the city mains. The lack of water caused not only personal inconvenience and business paralysis, but it occasioned real danger of disease through unflushed sewers and insufficiently drained pipes.

The conservation of our forests means the conservation of our waterways, whether these be used for transportation or as sources of drinking water.

CHAPTER XXXVI

WATER MAKES A GARDEN OF THE DESERT

The source of water. — In the beginning, the earth was stored with water just as it was with metal or rock. Some of the water gradually took the form of rivers, lakes, and streams, and it is this original supply of water which furnishes us all that we have to-day. We quarry to obtain stone and marble for building, and we fashion the earth's treasures into forms of our own, but we cannot create these things. We bore into the ground and drill wells in order to obtain water from hidden sources, and we utilize rapidly flowing streams to drive the wheels of commerce, but the total amount of water remains unchanged.

Although the amount of water remains the same, its form changes. The sun's heat evaporates it and causes it to mingle with the atmosphere. In time, this water vapor cools, condenses, and falls as snow or rain. The water thus returns to the earth, feeds rivers, lakes, springs, and wells, and in time is again changed to vapor by the sun's warmth.

When rain falls upon a field, some of it collects in puddles and quickly evaporates back into the air; some of it runs off and drains into small streams or into rivers and sooner or later evaporates and becomes water vapor; and the rest of it soaks into the ground and slowly feeds springs and wells.

Water which soaks into the ground moves slowly downward. But after a longer or shorter journey it meets with a non-porous layer of rock which hinders its downward passage. If the rock

is not level, the water does not "back up" above it, but flows onward parallel with it. In some distant region the underground water finds an outlet for itself and forms a spring (Fig. 213).

The streams flowing from springs join other streams and these eventually join larger streams or rivers. From the surface of the water evaporation occurs, and vapor passes into the atmosphere, where it is condensed and again falls to the earth.

Fertile plains and deserts. — A traveler on his way from New York to California leaves regions of luxurious vegetation, passes through dry parched plains clothed only here and there with a scanty vegetation, and finally

FIG. 213. — How springs are formed. *A*, porous layer; *B*, non-porous layer; *C*, spring.

ends his journey in a land of rich and varied vegetation. In the East and middle West profitable farming lands appear on every hand, in the far West desert wastes extend as far as the eye can reach (Fig. 214), and not until the lands lying on the Pacific Ocean are reached do vineyards, orchards, and farms reappear. There is only one explanation for these striking contrasts, namely, differences of rainfall. Enough rain falls in one year in the East to make a layer of water about 60 inches deep; so little falls on the dry western sections that it would take about seven years to make a layer of the same depth.

Plants, like all other living things, require food. Some of this they get from the air through leaves, some they absorb from the soil through roots. But if the soil is so dry that there is not enough moisture to dissolve soil food, the plant dies, even

A large, empty rectangular area representing a desert landscape.

FIG. 214. — Desert wastes.

though it is surrounded by an abundance of solid soil food. Then too, plants need water in order to manufacture starch out of the materials taken from the air. They also need water

A large, empty rectangular area representing a grass-covered prairie.

FIG. 215. — Grass-covered prairie.

to distribute the manufactured food to all parts of the plant. Scarcity of rainfall means a parched, dry soil, and starvation for plants.

The rainfall of the East is sufficient to support plants in abundance, from low grass to tall forest trees. The rainfall of the middle West is less abundant, fine large trees are scarce,

and grasses cover the prairies (Fig. 215). In the desert regions the rainfall is meager and the land is dotted here and there with a scanty plant growth totally different from that of well-watered regions. There are two conspicuous desert regions in the United States. One consists of portions of Utah, Nevada, California, Arizona, and neighboring states; the other includes portions of Arizona and New Mexico and extends into

FIG. 216. — Barrel cactus.

the adjoining country of Mexico. In both of these regions there are vast areas almost without plant life; but, generally, plants are huddled together in scattered patches on the dry land (Fig. 214). Owing to the scarcity of water in the soil, each plant needs a large space from which to draw its supply. For this reason the vegetation is scattered and interrupted by stretches of barren soil. To get sufficient water small shrubs like the mesquite sometimes send roots 50 feet from the parent in search

of it. Some plants, like the barrel cactus (Fig. 216), absorb large amounts of water in times of rains and store it for months in swollen stems and roots. They thus tide themselves over the long drought which intervenes between rainy seasons.

Desert plants are very different in structure and appearance from plants in well-watered regions (Fig. 217). This is largely because they have devices for safeguarding themselves against the loss of water. All plants evaporate moisture through

FIG. 217. — Desert vegetation.

their leaves; a good healthy sunflower plant loses on a warm dry day one pint of water by evaporation; a large tree loses barrels of water. Where rainfall is plentiful and ground water is abundant this loss of water by evaporation is made good by absorption from the soil. Where rain and soil water are meager, as in deserts, there is no way of making good this loss, and some means of preventing it is necessary. Desert plants are constructed in such a way that they get a large quantity of water from the ground, lose little of it (Fig. 218), and store much of it over the dry seasons. The mesquite has unusually long roots which take water from a large area; the barrel cactus through its swollen stem stores water in seasons of plenty for use in seasons of drought. The ocotillo (Fig. 219)

has small leaves through whose surface little water evaporates. Some plants lack leaves but have instead stiff hard thorns through which water cannot easily escape; other plants have leathery



FIG. 218. — Yucca, with stiff narrow leaves through whose surface little water escapes.

leaves, which are almost impervious to water and hold it safe in spite of hot, dry winds. In the desert only those plants grow which are able to meet desert conditions by having special means of securing water, of storing water, and of preventing its escape through evaporation.

The cause of scant rainfall. — In the East, winds saturated with moisture blow in from the Atlantic Ocean and move westward over low-lying lands. As the winds travel onward their water vapor gradually condenses and falls on the land as life-giving rains; seeds sprout, vegetables thrive, fruits ripen, and forest trees

grow in strength and beauty. In the West, moisture-bearing winds blow in from the Pacific Ocean, but they soon meet a mountain range (Fig. 220), which robs them of much of their moisture because as winds rise to pass over mountains

they become chilled and lose moisture by condensation. The moisture which condenses falls on the mountain slopes as snow or rain. The winds continuing their eastward journey soon encounter the great peaks of the Sierra Nevada, where they lose more moisture by condensation. The winds which leave the Sierra Nevada are poor in moisture and give little to the thirsty plains beyond. Finally, the nearly dry winds encounter the Rocky Mountains and in rising over these towering peaks lose practically the last remnant of their moisture. Such winds blow onward with almost nothing for the lands beyond, which therefore lie parched and barren.

FIG. 219. — The ocotillo. This tree is in full bloom although its leaves can hardly be seen.

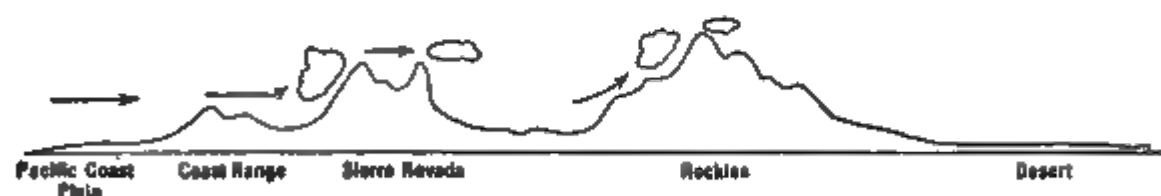


FIG. 220. — High mountains rob winds of their moisture.

The "lay of the land" is responsible for meager rainfall in our desert lands.

Irrigation. — Many western plains and valleys which lack rainfall have large rivers fed by rains falling on distant mountains. By using the waters of these rivers for irrigation much of the barrenness due to scant rainfall has been overcome.

Ditches have been built, pipes have been laid, and water has been diverted from the rivers to remote ranches and farms (Fig. 221).

When arid lands were artificially watered, they proved wonderfully fertile and yielded large crops, and many settlers were attracted to them. As more and more people settled on the lands and sought to make their living from them, the problem of irrigation became more difficult. To obtain water sufficient for all, it was necessary to tap distant rivers and to build huge canals. Sometimes mountains intervened between the arid region and the rivers, and canals had to be cut through solid

FIG. 221. — Irrigation canal into which water is diverted for distant ranches.

rock. At other points trestles had to be built across chasms as supports for huge pipes or flumes through which water was conveyed.

“Soon, the miracle wrought when water was supplied to the sun-baked land—the fields of splendid grain and the gardens of fruit that replaced the barren region—spurred men on to even greater tasks of engineering.” It was determined to utilize the tremendous amount of water wasted during the early spring thaws. At the approach of mild spring weather, snow melts rapidly and flows down the mountains faster than neighboring streams can carry it away. The streams overflow their banks, flood the country, and bring destruction. Engineers proposed to store in reservoirs and dams (Fig. 222)

the water yearly wasted during freshets, and to send it gradually down to the low land when needed for irrigation. Dams several hundred feet high were needed to hold back the waters; artificial lakes many miles in extent were required to store the

FIG. 222. — Storage reservoir.

water, and tunnels miles long were necessary to carry the water from reservoir to ranch.

Private enterprise was unable to supply the millions of dollars needed for these undertakings, and in 1902 the government came to the rescue of the arid lands, and passed the Reclamation Act. By this act Congress was authorized to begin the work of irrigation in the arid western regions. Among the many interesting projects undertaken by the government is that known as the Uncompahgre Project in the western part of Colorado. A part of the Uncompahgre Valley had been irrigated for years by the Uncompahgre River. But the river is small, and could irrigate only a portion of the valley through which it flowed. Some miles distant, however,

is a second river, the Gunnison, which has a supply of water more than sufficient for its own valley. But a range of hills 2000 feet high separates the two rivers. Engineers of the Reclamation Service blasted a tunnel through these mountains, turned the water of the Gunnison through the tunnel,

FIG. 223. — The orchard is irrigated by turning water into the furrows.

and allowed it to flow down into the Uncompahgre. This gave the Uncompahgre the water necessary to irrigate its whole valley, and to-day thousands of fertile acres replace the desolate waste of a few years ago (Fig. 223).

When all the streams in the arid West have been made use of for irrigation, millions of acres of useless arid land will have been converted into rich farms.

CHAPTER XXXVII

THE WORK OF RUNNING WATER

The solvent action of water. — The power of water in stream, lake, and ocean is evident to all, but the activity of ground water, that is, rain water which sinks into the earth and moves through it, is not so generally known. The real activity of ground water is due to its power to dissolve minerals and gases. When rain falls it dissolves substances floating in the atmosphere, and when it sinks into the ground it dissolves materials out of rocks. A proof of the presence of mineral matter in water is seen in the crust or coating which accumulates on the inside of a kettle in which water is boiled. The crust is an accumulation of minute particles of mineral matter which was left behind when the water evaporated.

The abundance of ground water beneath the surface of the earth is shown by the numerous springs which gush out of the ground and by the numerous wells which supply water. Springs and wells fed by waters rich in minerals are called mineral springs and mineral wells. The quantity of mineral matter in some springs is surprisingly large. The famous springs of Bath, England, contain so much mineral matter in solution that a column 6 feet in diameter and 140 feet high could be built out of the mineral matter contained in the water consumed yearly by the townspeople. A German spring yields water from which enough salt could be taken in a year to fill completely a good-sized house. There are many mineral springs in the United States; among the best known

are the Hot Springs of Arkansas and Saratoga Springs, New York. In 1910 about 60,000,000 gallons of water were taken from mineral springs in the United States and sold for over \$6,000,000. Springs which contain iron, sulphur, and magnesium are thought to have a beneficial effect on the body and are called medicinal springs. Vichy in France, Hunyad in Hungary, and Karlsbad in Bohemia are well-known medicinal springs.

The destructive action of ground water. — Water is a destructive agent. It forms underground caves and caverns by dissolving and carrying away in solution large masses of rocks. It makes rock porous and weak by removing soluble materials

and leaving pores and cavities in the insoluble portions, and it causes rock to crumble into sand and gravel. Limestone is so readily soluble in water containing carbon dioxide in solution, that numerous holes and

FIG. 224. — Showing how caves and holes are formed by the solvent action of water.

cavities are eaten out of it and after a long time caverns are formed. Mammoth Cave of Kentucky and Wyandotte Cave of Indiana are caves formed in limestone by the solvent action of ground water (Fig. 224). The thinned and weakened roofs of caves sometimes fall in and dangerous sink holes are formed. Where these holes are numerous land cannot be cultivated or used for pasture, and is worthless to the farmer.

Sandstone and conglomerate through which water flows lose their cementing materials and crumble into sand and gravel. Rocks are not equally soluble in water; some, like limestone, are easily soluble, others are so little soluble that there is no perceptible change in years. A peculiar appearance

is given to rock (Fig. 225) when weak soluble parts are eaten away, and stronger less soluble parts are left unchanged. Granite, for example, consists of more soluble and less soluble materials, and the rapid disappearance of the soluble parts and the persistence of the more resistant parts are responsible for the peculiar shapes and forms noticed in underground granite rock.

Ground water feeds streams and rivers. These finally make their way to the sea. The sea owes its saltiness to ground water which flows through rock containing the constituents of salt; it owes its lime

FIG. 225. — The work of water as a solvent.

to ground water which flows through rock containing lime. Ground water yearly contributes to the sea millions of tons of valuable mineral matter.

Movements of ground water. — Wells run dry and springs sometimes cease to flow in dry seasons when rain does not fall. The springs bubble forth again when the drought is broken by plentiful rains and water returns to the wells. There is a close relation between rain water and ground water because ground water is water and snow which have sunk below the surface. Rain sinks into the ground by means of

pores and openings in the soil and rock. The spaces between sand and gravel particles are so large that considerable water runs quickly through them. The spaces in clay, which is dense and compact, are so small that little water runs through them. The larger and more numerous the openings in the soil, the greater is the quantity and speed of the water which flows down through it. Beneath the loose soil there is rock, through which the water must flow or seep. The farther below the surface these rocks are, the more pressed and compact are they, and the smaller are their pores and cracks.

Water seeps so slowly through the deep underground rocks that it accumulates around them and saturates them with water. When the downward flow is stopped, much of the

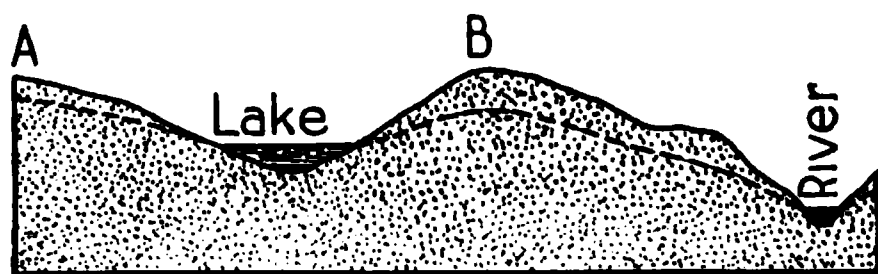


FIG. 226. — Diagram showing the relation of the level of ground water (the broken line) to the surface of the ground and to a lake and river.

water backs up and fills the ground. The level below which the ground is saturated with water is called the level of ground water or the water table. Wells sunk to this depth always yield

water. The water table or the level below which the ground is saturated with water varies from time to time. In rainy seasons the water table is high; in dry seasons it is low. The wise farmer digs a well which is deep enough to be below water level at all times. The water level varies from place to place; in regions of abundant rainfall it is higher than in regions of scanty rainfall; in valleys it is nearer the surface than in mountains; in some areas it is so far below the surface that wells must be sunk thousands of feet to reach it. In other areas it is so near the surface that it forms marshes; and it may even come to the surface and form lakes and ponds. A lake is shown in Figure 226, formed by a high water level.

The constructive action of water. — Water does not always act as a destructive agent; what it breaks down in one place it builds up in another. It does this partly by means of precipitation. Water dissolves salt, and also dissolves lead nitrate, but if a salt solution is mixed with a lead nitrate solution, a solid white substance is formed in the water. This formation of a solid substance from the mingling of two liquids is called precipitation (Fig. 227). Such a process occurs daily in the rocks beneath the surface of the earth.



FIG. 227. — From the mingling of two liquids a solid is sometimes formed.

Suppose water from different sources enters a crack in a rock, bringing different substances in solution. The mingling of the waters may cause precipitation; and the solid thus formed will be deposited in the crack and fill it up. Hence, while ground water tends to make rock porous and weak by dissolving out of it large quantities of mineral matter, it also tends to make it more compact because it deposits in cracks, crevices, and pores mineral matter precipitated from solutions. When the mineral matter precipitated from the solutions is deposited in cracks, *veins* are formed, which may consist of the ore of different metals, such as gold, silver, copper, or lead (Fig. 228). Man is almost entirely dependent upon these veins for the supply of metal needed in the various industries, because in the original condition of the rocks, the metallic substances are so scattered that they cannot be profitably extracted. The veins are not always composed of one substance, because several different precipitates may be formed. But there is a decided grouping of valuable metals.

The destructive and constructive actions of water are constantly at work. In some places the destructive action is more prominent, in other places the constructive action; but always

FIG. 228. — Veins of calcite in a volcanic rock.

the result is to change the character of the original substances and to modify the land.

Streams wear away the land. — Small streams and rivers work more rapidly than ground water and are more effective in producing visible changes in the land. Rivers swollen by heavy rains and spring thaws sweep away bridges, railroad tracks, and houses, destroy thousands of acres of crops, uproot whole groves of trees, tear away banks, cut out rocky slopes, and form new channels. But without streams there would be no inland navigation, thousands of mills run by water would be shut down, irrigation would be unknown, the air would become dry for lack of moisture, and existence on the earth would be impossible.

When rain runs down a slope, it picks up soil particles and carries them to the streams into which it flows, making the streams muddy for miles. In some parts of the country all loose soil has been torn from hillsides by heavy rains and has

been washed into rivers. Many a farmer dreads the heavy rain which washes or erodes away his top soil and leaves ruts and

FIG. 229. — A gully worn out by erosion.

gullies on his farm (Fig. 229). Streams and rivers flow toward the sea and carry with them sand, pebbles, and *débris*. When rocks are exposed along streams, they weather and crumble into fragments which slowly slide down into the water flowing at the foot of the rocks. Rocks and stones, dislodged by rain, wind, and animals, fall into streams, loose soil slips slowly down hills and also becomes part of the stream. A river is loaded by these materials, and it adds to this load by picking up loose materials from its bed and banks. All of this load the river carries to the sea. Sand and loose soil particles are carried in suspension as sediment buoyed up by constantly eddying currents. Substances dissolved from

FIG. 230. — These rocks are rolled downstream at high water.

the rocks are carried in solution. Gravel, pebbles, and big stones are too heavy for the stream to lift, but they are rolled and dragged along (Fig. 230). As the river sweeps onward, the gravel, stones, and boulders which it carries rub and grind against the soft banks and bottom and set free new particles that are carried away in suspension, or they hit against rocky banks and bottom and chip off small and large pieces of rock. These new rock pieces are in turn rolled and dragged along



FIG. 231. A stream wearing away its bank

by the stream and serve as additional tools in its work of tearing, cutting, and grinding. As a result of the grinding and rubbing, the stream bed deepens and the banks wear away or erode (Fig. 231). Rivers whose beds and banks are of rocky material too heavy to be borne

away do not deepen their channels and wear away their banks as rapidly as rivers whose beds and banks are made up of sandy or loose soil. The Tennessee River is eroding its banks and is giving great anxiety to the farmers who own land along its course.

Streams build up land. — Rain flowing down a gully carries away soil but drops most of it at the base of the gully (Fig. 229). Mountain streams deposit great masses of *débris* at the foot of the mountain where they change from steep swift-flowing mountain streams to gentler-sloping, quieter valley streams. The load that a stream can carry depends

upon the swiftness with which it runs: when it flows swiftly in hilly, mountainous regions, it can carry a great load; but when its speed is suddenly checked, as at the base of a hill or ravine, it cannot carry so much, and deposits sediment and débris. Material deposited by streams at the foot of steep slopes accumulates in the form of a cone or fan, and is called an alluvial fan (Fig. 232). Continual deposits increase the size of the fan, which in time becomes so large that it obstructs the stream which created it, and forces the stream to take a longer, slower route around it. The water which flows around the fan adds to its size by fresh deposits along its edge; thus the fan

FIG. 232. - An alluvial fan on which trees are growing.

grows and sometimes it becomes miles wide and hundreds of feet thick. Alluvial fans 40 miles wide exist in California. They make excellent farm lands and support abundant crops.

Rivers that flow over steep lands move swiftly and gather a load; rivers that flow over gently sloping land move less rapidly and deposit sediment. The slope or gradient of a stream generally becomes less and less as the river flows onward toward the ocean, and the load that the stream can carry becomes less and less. The load that the slowly moving river cannot carry is deposited on the stream bed or is spread over the valley through which it flows. That which is deposited on the bottom fills up the channel, and may form sand bars or even islands in the river (Fig. 233). The sediment brought to the

Mississippi River by swift streams which flow into it and the sediment dropped by the slow-moving river is so large that the

FIG. 233. — River deposits. The river breaks up into numerous small and shallow streams.

channel of the river fills up quickly and in places must be dredged yearly.

When a river flows into a gulf or sea, its speed is suddenly checked and its load is quickly dropped. The Mississippi River deposits in the Gulf of Mexico about 1,000,000 tons of sediment a day. Some of this enormous mass is swept far out to sea by waves and tides; the rest of it accumulates where it drops and builds up new lands called deltas. So great have been the past deposits of the Mississippi River at its mouth in the Gulf of Mexico that a delta has been formed covering as much area as Massachusetts and Connecticut. So large are the present deposits of the river that the delta is enlarging at the rate of one mile in six years. Deltas are fertile and yield good harvests but they are low and are frequently flooded, and crops on them are lost and people are drowned. In many places dikes and embankments are built around deltas as safeguards against floods.

Very often a river flows with such a speed that it deposits as much as it carries away. The Missouri River does this in one part of its course.

Sometimes a river flowing through a level region deposits sediment so quickly that its channel fills up rapidly. The



FIG. 234. — A flood plain formed in a narrow valley.

river then spreads itself over a larger area and may break up into numerous shallow streams. The Platte River, Nebraska, is an illustration of such a condition. Banks which are cut into and worn down by rivers, and sediment which is spread over valleys by rivers form low plains. Such low plains are called flood plains (Fig. 234), because in times of flood they are apt to be covered with water. The Mississippi River has formed in the lower part of its course a flood plain 60 miles wide. Flood plains are flat fertile lands which are easy to till

and to harvest. But because they are sometimes flooded they are uncertain homes unless embankments are built along the rivers to protect them.

How rivers and valleys may be formed. — The earth is constantly changing. In some places streams dry up, in other places new streams form, and everywhere old streams change their courses and alter the lands through

FIG. 235. — A mountain ravine.

which they flow. Great changes such as the growth of a full-fledged river and valley take place slowly, requiring millions

of years, but small changes occur daily and can be seen on every hand. This is especially true after a severe rain or wind storm; gullies are formed in field and on hill, banks washed away, rocks thrown upon river banks, and new channels formed by swift waters. The gully developed by a single rain may be the beginning of a ravine, a gorge, a valley, because, although it is small, a mere crack in the soil, it grows longer, wider, and deeper with each successive rain. The rain which runs into a gulley from its head lengthens it,

FIG. 236. — A stream widening its valley by cutting into its bank.

that which runs down its sides widens it, and that which flows over its bottom deepens it. In time it becomes a ravine (Fig. 235), down which a stream courses wildly during rain, but in which there is no trace of a stream in clear weather. A ravine, like a gully, lengthens, widens, deepens with each rain. As it deepens it gets nearer and nearer the ground water level and finally reaches it; ground water then seeps continually into it and gushes through openings found in weak places. The ravine becomes the bed of a permanent stream.

The depression in which a permanent stream runs widens

and deepens very much as the gully widened and deepened. Rain, snow, and wind erode the banks, washing away soil and causing the slopes to recede. Stones and pebbles roll along the bottom wearing it down deeper and deeper. Deepening of the bottom usually takes place faster than widening of the banks, and young streams generally flow at the base of steep slopes. But deepening of the river bottom does not continue indefinitely, because every stream flows into a larger body of water such as a bay or gulf, and cannot cut its channel lower than that of the stream into which it empties. When a stream has cut to this level, that is to base level, it ceases to deepen its valley.

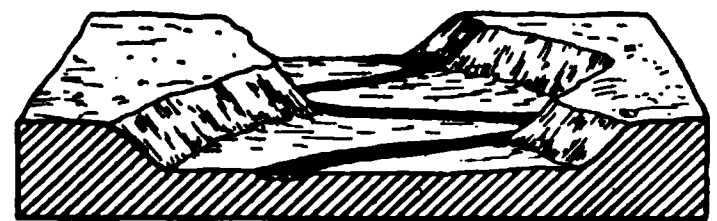
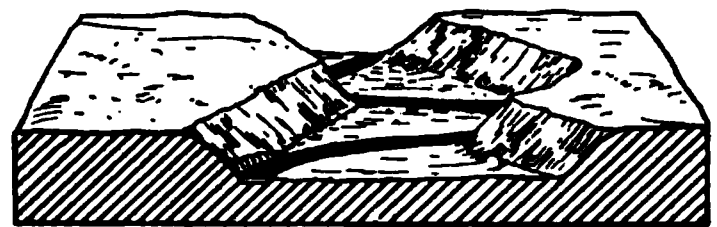
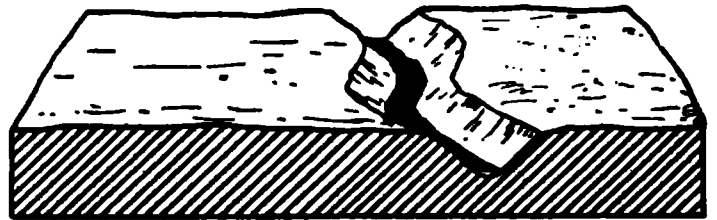


FIG. 237. — As a river approaches base level, it widens its valley by side cutting.

Although the valley ceases to deepen, it does not cease to widen, indeed it widens more rapidly than before. When water has a small gradient and a low velocity, it deposits sediment. The channel fills up and its water in consequence spreads over the land and forms a wider valley. The valley also widens because the river continues to cut into its banks and to wear them away (Figs. 236 and 237). Slowly moving water does not forge ahead and overcome obstacles, but winds back and forth around them taking the easiest path to be found at the moment. It winds around first one bank and then another,

cuts into each, thus opening out its valley and forming valley plains.

Old and young rivers and valleys. — As we travel through the country we see valleys of all kinds: narrow valleys with steep banks (Fig. 238); wide valleys with gently sloping banks; wide, nearly level valleys bounded by low, gently sloping hills.

FIG. 238. — A valley in which deepening has progressed faster than widening

The narrow, steep, high-banked valleys are young, and erosion has not been going on long enough to level their beds and banks. The wide, more gently sloping valleys with lower banks are older, and erosion has been going on long enough to lessen the gradient of the valley floor and to reduce the steepness of the slopes. The wide, almost level valleys bounded by low, sloping hills are old, and erosion has been in progress long enough to level down the land nearly to flatness. Small, narrow, and steep valleys are called gorges; large, narrow, and

steep valleys are called cañons (Fig. 239). The Colorado Cañon is the largest in the world. It is many miles long and a mile deep, with almost perpendicular walls. In time cañons and gorges change into open and level valleys, because the streams which run through them ultimately cut down to base level.

FIG. 239. — In the Yellowstone Cañon.

When base level has been reached, deepening of the valley ceases, but widening continues.

In young rivers, waterfalls and rapids are abundant (Fig. 240), since the gradient is steep and irregular; in older rivers, waterfalls and rapids are scarce and even lacking. The stage to which a river and a valley have progressed influences the life and customs of the people in the region. A young valley with steep slopes is unsuitable for farming, but its rapidly flowing

waterfalls furnish power for mills, factories, electric railways and lighting, and industries spring up and the inhabitants become industrial rather than agricultural. In the old valleys, the slopes are gentle and the floor broad and fertile and adapted to farming; water power is low and too meager for manufacture, and agriculture is the principal means of livelihood. Navigation is difficult and even dangerous in the younger valleys, transportation is limited to railroads, and commerce is retarded by

FIG. 240. — A waterfall.

lack of outlets to markets. Navigation in older rivers is easy, transportation is cheap, and a natural outlet to the commercial

FIG. 241. — Waves beat unceasingly against the shore.

markets insures thrift and success. Because rivers are the sole highways of travel and trade in new countries settlements grow up around them and form the beginnings of future cities. As the country grows and progresses, trolley lines and railroads

FIG. 242. — Dangerous sea cliffs in northwestern France.

penetrate into the lands remote from rivers and allow the spread of population.

Oceans cause changes in land. — Rivers modify inland regions, oceans modify seashores and coast lines. Oceans wear back the shore and change its outline; they hurl sediment on shores and form beaches; they deposit sand on

shallow bottoms and build reefs and sand bars; and they form dangerous cliffs along the shore. Waves beat unceasingly against the shore (Fig. 241) and, armed with sand, pebbles, and even boulders, erode it and cause the shore line to retreat. Large waves are more powerful than small ones and coasts whose surf is heavy are worn more than coasts whose surf is light. A coast of sand, pebbles, and loose material like that at Atlantic City is

FIG. 243. — Thick masses of seaweed help to protect a coast.

cut into more than a rocky coast. An island off the northern coast of Germany has been so worn away that it is now only one twentieth of its former size. Irregular, dangerous coasts are made where rocks of hard and soft materials are beaten by the sea. The softer portions are worn away, but the more resistant parts remain and endanger ships. Sometimes cliffs of enormous size tower high above the waves

and bear evidence of constant struggle against wave destruction (Fig. 242).

Man's means of overcoming loss of land. — Oceans like rivers level down high places and build up low places. In doing this they often cause serious inconvenience and loss to man. The building up of sand bars dangerous to commerce is no return to the farmer for fertile soil carried away by streams; neither is the piling up of soil on the ocean bottom any return for a retreating shore line and loss of beach. In general, water removes soil from places where it is useful and transfers it to

FIG. 244. — Mangroves in Florida.

places where it is useless and even harmful. There are several methods of lessening land erosion and loss of land. In Boston harbor, for example, sea walls have been erected as a protection against waves; and in places along the shores of the Mississippi River willow trees have been planted as water breaks. Plants are an excellent protection against waves. Where thick masses of seaweed abound (Fig. 243), the rocks are less worn because plants "give with" the waves and form an elastic covering against which waves beat with little result. Along the New

Jersey coast marsh plants abound and serve as a shield against waves; in addition they entrap and entangle sediment washed in by waves, and thus they add to the shore. In Florida mangrove trees protect the coast (Fig. 244).

Plants are one of the best means of protection against stream erosion. Slopes covered with vegetation do not have their fertile soil washed away by the rain. The soil in which plants grow is kept open and loose by the growing roots and quickly absorbs water which falls on it; thus water which would have been carried away, is itself entrapped and held fast. Then, too, roots act as nets to the soil and prevent its escape; landslides seldom occur on thickly wooded slopes, but occur frequently on barren hillsides. Cultivation of plants on hillsides and along streams is one of the simplest and surest methods of preventing loss of land.

CHAPTER XXXVIII

AIR

The instability of the air. — We are usually not conscious of the air around us, but sometimes we realize that the air is heavy, while at other times we feel the bracing effect of the atmosphere. We live in an ocean of air as truly as fish inhabit an ocean of water. If you have ever been at the seashore, you know that the ocean is never still for a second. Sometimes the waves surge back and forth in angry fury, at other times the waves glide gently in to the shore and the surface is as smooth as glass; but we know that there is perpetual motion of the water even when the ocean is in its gentlest moods. Generally our atmosphere is quiet, and we are utterly unconscious of it; at other times we are painfully aware of it, because of its furious winds. Then again we are oppressed by it because of the vast quantity of vapor which it holds in the form of fog or mist. The atmosphere around us is as restless and varying as is the water of the sea. The air at the top of a high tower is very different from the air at the base of the tower. Not only does the atmosphere vary greatly at different altitudes, but it varies at the same place from time to time, at one period being heavy and raw, at another being fresh and invigorating.

Winds, temperature, and humidity all have a share in determining atmospheric conditions, and no one of these plays a small part.

The character of the air. — The atmosphere which envelops us at all times extends more than fifty miles above us, its height being far greater than the greatest depths of the sea.

This atmosphere varies from place to place; at the sea level it is heavy, on the mountain top less heavy, and far above the earth it is so light that it does not contain enough oxygen to

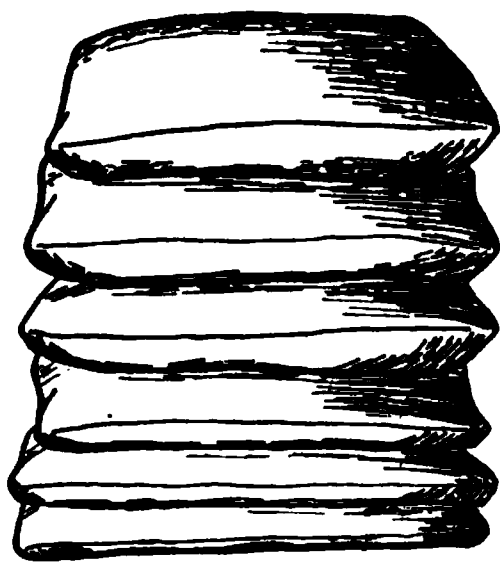


FIG. 245. — To illustrate the decrease in pressure with height.

permit man to live. Figure 245 illustrates by a pile of pillows how the pressure of the air varies from level to level.

Sea level is a low portion of the earth's surface; hence at sea level there is a high column of air and a heavy air pressure. As one passes from sea level to mountain top a gradual but steady decrease in the height of the air column occurs, and a gradual but definite lessening of the air pressure.

Air pressure. — When an empty tube (Fig. 246) is placed in water, the water does not rise to the top of the tube. But if the tube is put in water and the air is then withdrawn by suction, the water rises in the tube (Fig. 247). This is what happens when we take lemonade through a straw. When the air is withdrawn from the straw by the mouth, the pressure within the straw is reduced, and the liquid is forced up the straw by the air pressure on the surface of the liquid in the glass. Even the ancient Greeks and Romans knew that water would rise in a tube when the pressure within the tube was reduced, and they tried to obtain water from wells in this fashion. But the water could never be raised higher than 34 feet. Let us see why water could rise 34 feet and no more. If an empty pipe is placed in a cistern of water, the water in the pipe does

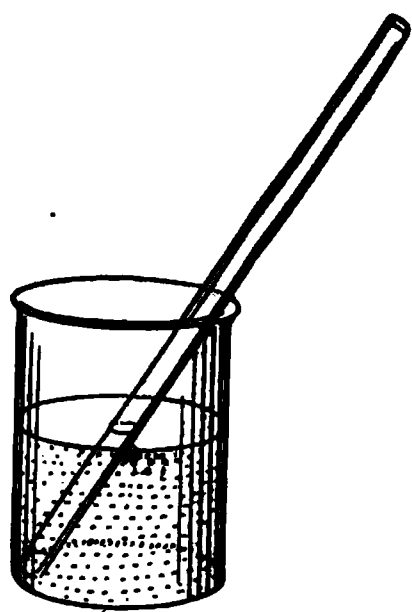


FIG. 246. — The water in the tube is at the same level as that in the glass.

not rise above the level of the water in the cistern. If, however, the pressure in the tube is removed, the water in the tube rises to a height of 34 feet approximately. If now the air pressure in the tube is restored, the water in the tube sinks again to the level of that in the cistern. The air pressing on the liquid in the cistern tends to push some liquid up the tube, but the air pressing on the water in the tube pushes downwards, and tends to keep the liquid from rising, and these two pressures balance each other. When, however, the pressure within the tube is removed, the liquid rises because of the unbalanced pressure which acts on the water in the cistern.

If water were twice as heavy, just half as high a column would be supported by the atmosphere. Mercury is about thirteen times as heavy as water and, there-

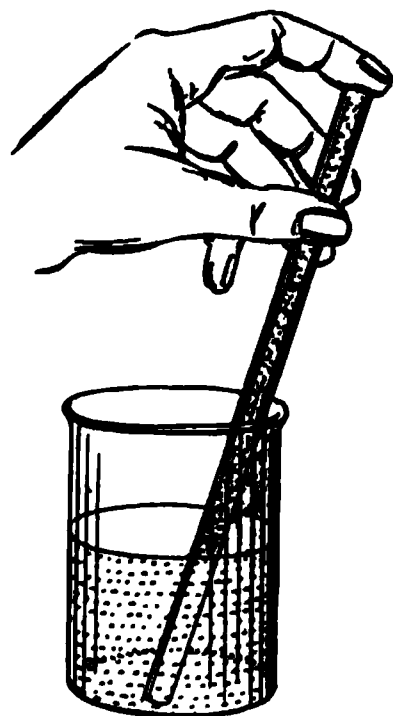


FIG. 247. — Water rises in the tube when the air is withdrawn.

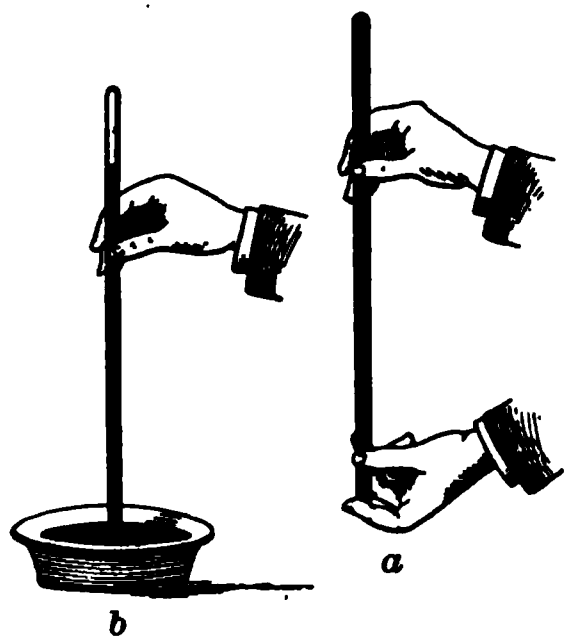


FIG. 248. — The air supports a column of mercury 30 inches high.

fore, the column of mercury supported by the atmosphere is about one thirteenth as high as the column of water supported by the atmosphere. This can easily be demonstrated. Fill a glass tube about a yard long with mercury, close the open end with a finger, and quickly insert the end of the inverted tube in a dish of mercury (Fig. 248). When the finger is removed, the mercury falls somewhat, leaving an empty space, or vacuum, in the top of the tube. If we measure the column in the tube, we find its height is nearly 30 inches, or about one thirteenth of 34 feet, exactly

what we should expect. Since there is no air pressure within the tube, the atmospheric pressure on the mercury in the dish is balanced solely by the mercury within the tube, that is, by a column of mercury 30 inches high.

The barometer. — Since the pressure of the air changes from time to time, the height of the mercury changes also. When the air pressure is heavy, the mercury is high; when the air pressure is low, the mercury shows a shorter column. By reading the level of the mercury one can learn the pressure of the atmosphere. If a glass tube and a dish of mercury are attached to a board and the dish of mercury is inclosed in a case for protection from moisture and dirt, and if a scale of inches is made on the upper portion of the board, we have a mercurial barometer (Fig. 249).

FIG. 249. — A simple barometer.

If the barometer is taken to the mountain top, the column of mercury falls gradually during the ascent, showing that as one ascends, the pressure of the air decreases. Observations similar to these were made by Torricelli as early as the seventeenth century. Taking a barometric reading consists in measuring the height of the mercury column supported by the atmosphere.

A portable barometer. — The mercury barometer is large and inconvenient to carry from place to place, and a more portable form has been devised, known as the aneroid barometer (Fig. 250). This form of barometer is ex-

FIG. 250. — Aneroid barometer.

extremely sensitive; indeed, it is so delicate that it shows the slight difference between the pressure at a table top and the

pressure at the floor level. Aneroid barometers are frequently made no larger than a watch and can be carried conveniently in the pocket, but they get out of order easily and must be frequently readjusted. The aneroid barometer is an air-tight box whose top is made of a thin metallic disk which bends inward or outward according to the pressure of the atmosphere. If the atmospheric pressure increases, the thin disk is pushed slightly inward; if, on the other hand, the atmospheric pressure decreases, the pressure on the metallic disk decreases and the disk is not pressed so far inward (Fig. 251). The motion of the disk is small, and it would be impossible to calculate changes in atmospheric pressure without some mechanical device to magnify the slight changes in motion.

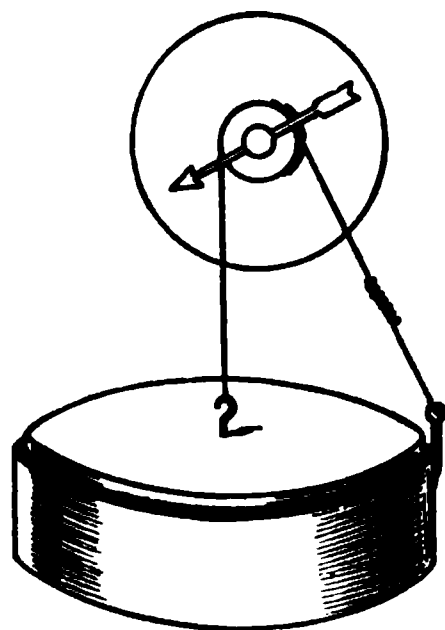


FIG. 251. — Principle of the aneroid barometer.

In order to magnify the slight changes in the position of the disk, the thin face is connected with a system of levers, or wheels, which multiply the changes in motion and communicate them to a pointer which moves around a graduated circular face.

The weight of the air. — We have seen that the pressure of the atmosphere at any point is due to the weight of the air column which stretches from that point far up into the sky above. This weight varies slightly from time to time and from place to place, but it is equal to about 15 pounds to the square inch, as shown by actual measurement. It comes to us as a surprise sometimes that air actually has weight; for example, a mass of 12 cubic feet of air at average pressure weighs 1 pound, and the air in a large assembly hall weighs more than 1 ton.

We are practically never conscious of this really enormous

pressure of the atmosphere, which is exerted over every inch of our bodies, because the pressure is exerted equally over the outside and the inside of our bodies; the cells and tissues of our bodies containing gases under atmospheric pressure. If, however, a finger is placed over the open end of a tube

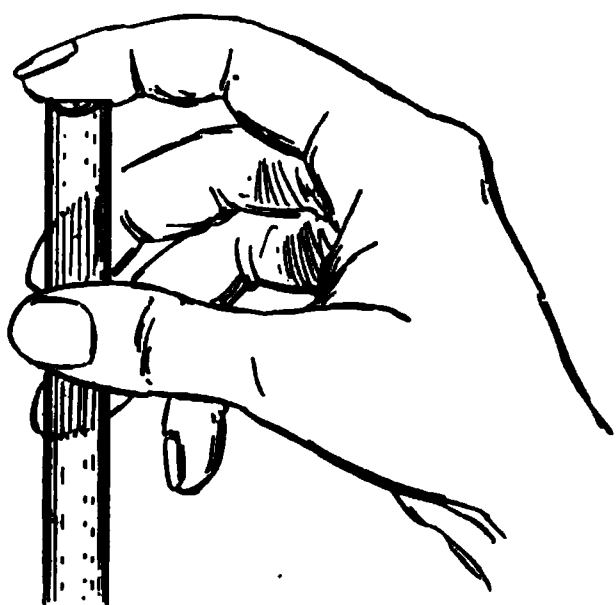


FIG. 252. — The flesh bulges out.

and the air is sucked out of the tube by the mouth, the flesh of the finger bulges into the tube because the pressure within the finger is no longer equalized by the usual atmospheric pressure (Fig. 252).

Aëronauts have never ascended much higher than 7 miles. At that height the barometer stands at 7 inches instead of at 30 inches, and the internal pressure in cells and tissues is not balanced by an equal external pressure. The unequalized internal pressure forces the blood to the surface of the body and causes rupture of blood vessels and other physical difficulties.

Use of the barometer. — Changes in air pressure are very closely connected with changes in the weather. The barometer does not directly foretell the weather, but a low or falling pressure, indicated by a fall of the mercury, usually precedes foul weather, while a rising pressure, indicated by a rise in the mercury, usually precedes fair weather. The barometer is not an infallible prophet, but it is of great assistance in predicting the general trend of the weather. Figure 253 shows a barograph or self-registering barometer which automatically records air pressure.

Seaport towns in particular, but all cities and villages, are on request notified by the United States Weather Bureau, ten hours or more in advance, of probable weather con-

ditions. In this way precautions are taken which annually save millions of dollars and hundreds of lives.

On a New Hampshire farm, not long ago, an old farmer started his farmhands haying by moonlight at two o'clock in the morning, because the Special Farmers' Weather Forecast of the preceding evening had predicted rain for the following day. His reliance on the weather report was not-misplaced, since the storm came with full force at noon. Sailing vessels,

FIG. 253. — Barograph.

yachts, and fishing dories remain within reach of port if the barometer foretells storms.

Isobaric and isothermal lines. — If a line were drawn through all points on the surface of the earth having an equal barometric pressure at the same time, such a line would be called an isobar. By the aid of these lines the barometric conditions over a large area can be studied. The Weather Bureau at Washington relies greatly on these isobars for statements concerning local and distant weather forecasts, any shift in isobaric lines showing change in atmospheric pressure.

If a line is drawn through all points on the surface of the earth having the same *temperature* at the same instant, such a line is called an isotherm (Fig. 254).

Weather maps. — Scattered over the United States are about 125 Government Weather Stations, at each of which three times a day, at the same instant, accurate observations of the weather are made. These observations, which consist of the reading of barometer and thermometer, the deter-

FIG. 254. — Isotherms.

mination of the velocity and direction of the wind, the determination of the humidity and of the rainfall, are telegraphed to the chief weather official at Washington. From the reports of wind storms, excessive rainfall, hot waves, clearing weather, etc., and their rate of travel, the chief officials predict what the weather conditions will be at a definite future time. In the United States, the *general* movement of weather conditions, as indicated by the barometer, is from west to east, and if a certain weather condition prevails in the west, it is probable that it will advance eastward, although with decided modifications. So many influences

modify atmospheric conditions that unfailing predictions are impossible, but the Weather Bureau predictions prove true in about eight cases out of ten.

The reports made out at Washington are telegraphed on request to any locality and are frequently published in the daily papers, together with the forecast of the local office. A careful study of these reports enables one to forecast to some extent the probable weather conditions of the day.

The first impression of a weather map (Fig. 255) with its various lines and signals is apt to be one of confusion, and the temptation comes to abandon the task of finding an underlying plan of the weather. If one will bear in mind a few simple rules, the complexity of the weather map will disappear and a glance at it will give one information concerning general weather conditions, just as a glance at the thermometer in the morning will give some indication of the probable temperature of the day.

Components of the air. — The best known constituent of the air is oxygen, already familiar to us as an active agent in the oxidation of most substances. Almost one fifth of the air which envelops us is made up of the life-giving oxygen. This supply of oxygen in the air is constantly being used up by breathing animals and glowing fires, and unless there were some constant source of additional supply, the quantity of oxygen in the air would soon become insufficient to support animal life. The unfailing constant source of atmospheric oxygen is plant life. The leaves of plants absorb carbon dioxide from the air and break it up into oxygen and carbon. The plant makes use of the carbon but rejects the oxygen, which passes back into the atmosphere through the pores of the leaves.

Although oxygen constitutes only one fifth of the atmosphere, it is one of the most abundant and widely scattered of

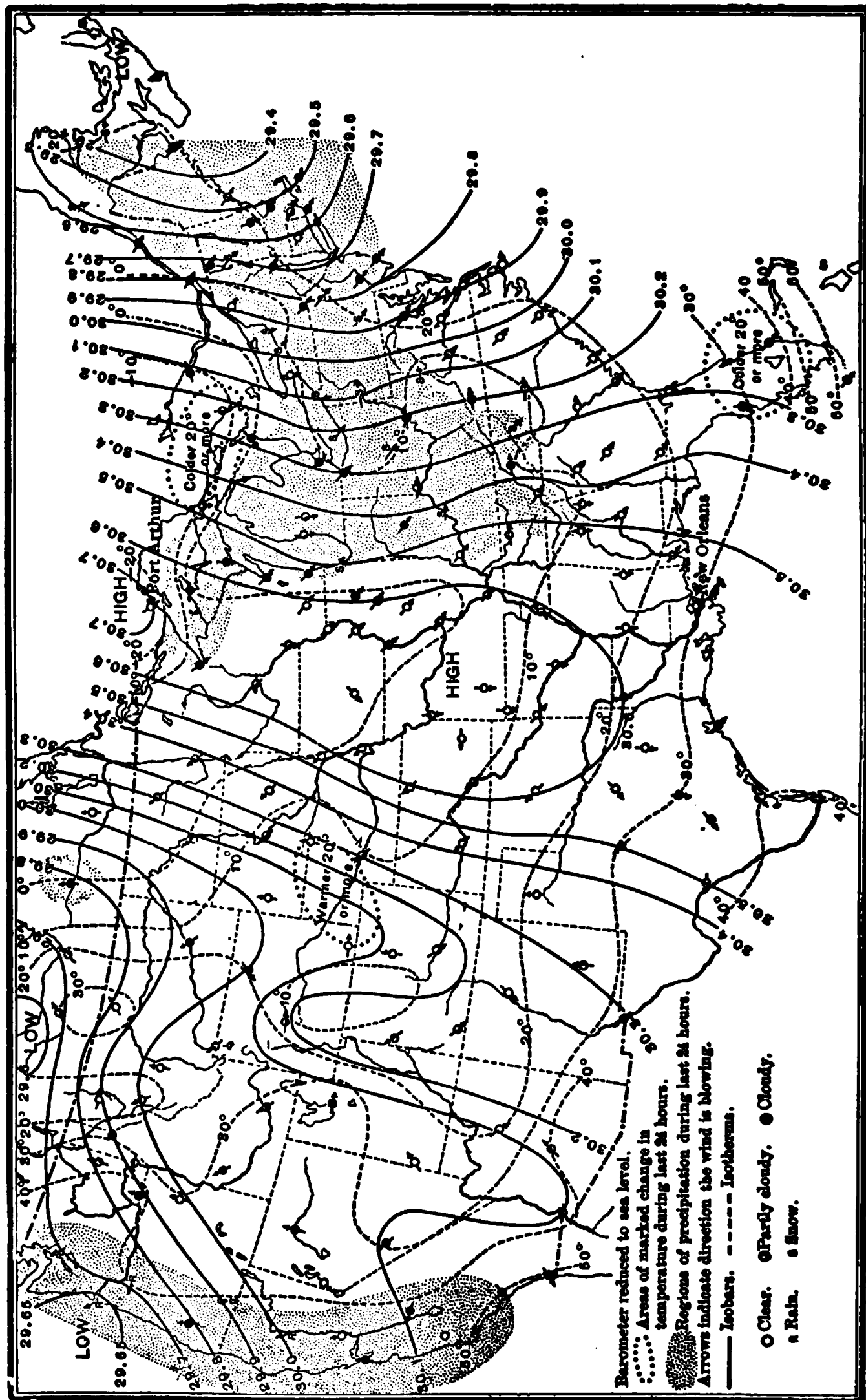


FIG. 255. — A weather map of the United States.

all substances. Almost the whole earth, whether it be rich loam, barren clay, or granite boulder, contains oxygen in some form or other; that is, in combination with other substances.

A less familiar but more abundant constituent of the atmosphere is nitrogen. The fact that the oxygen in air is diluted with so large a proportion of nitrogen prevents fires from sweeping over the world and destroying everything in their path. Nitrogen does not support combustion, and a burning match placed in a bottle of air goes out as soon as it has used up the oxygen. The nitrogen in the bottle not only does not assist the burning of the match, but it acts as a damper to the burning. Free nitrogen is not poisonous; but one would die if surrounded by it alone, just as one would die if surrounded by water. The vast supply of nitrogen in the atmosphere would be useless if the smaller amount of oxygen were not present to keep the body alive.

Another constituent of the air with which we are familiar is carbon dioxide. Even in pure air, carbon dioxide is present in very small proportions, being continually taken from the air by plants in the manufacture of their food.

Various other substances are present in the air in minute proportions, but of all the substances in the air, oxygen, nitrogen, and carbon dioxide are the most important.

CHAPTER XXXIX

THE WORK OF THE ATMOSPHERE

Dust. — Wind raises small dust particles aloft and carries them away and sweeps coarse sand particles into drifts on pavements and fields. The dust that settles on the deck of a ship in mid-ocean or on the newly fallen snow of the mountain is blown there by the wind. Shelves and tables in our homes need daily cleaning to keep them free from dust. Deserted houses are sometimes half hidden by the dust which falls on them; the ancient and deserted city of Nineveh is supposed to have been buried by dust. If the wind is gentle, we are not

conscious of the dust it carries; if it is strong, clouds of dust overtake us and make us conscious of its carrying power.

The cutting power of wind-blown sand. — On a windy day, the face is often stung by small soil particles blown against it. The fine sand carried by winds acts as a sharp tool and cuts and wears away glass, rock, and stone

FIG. 256. — A boulder etched by wind-blown sand.

on which it strikes. Windows and monuments are often badly scratched and marred by the sand hurled against them by wind. Figure 256 shows a sandstone boulder which has been worn away in part by the constant beating of wind-blown sand; the

ridged appearance of the rock is due to the fact that the soft parts of it have worn away more rapidly than the harder parts.

In regions where rainfall is abundant, the wind has few tools, because the soil is damp and the particles cling together and the wind cannot pick them up. But in arid regions, where the soil is dry and loose, the wind never lacks weapons and does considerable damage. In desert regions windows in railroad trains have been destroyed in a single day by sand storms.

Dunes. — Sand particles which are too heavy to be lifted are rolled and dragged along the ground until they meet an obstacle, such as a bush, a log, or a stone, which hinders their progress. There they lodge, forming mounds and hills (Fig. 257). In deserts and sandy valleys and on sea beaches, the ridges and mounds of wind-deposited sand are large and numerous and are called dunes (Fig. 258). In the dry regions of Kansas and Nebraska, on

FIG. 257 — Vegetation starts a sand dune and is then often overwhelmed by it.

the sandy shores of Lake Michigan, and along the New Jersey coast dunes are seen everywhere. Anything that serves as an obstacle to wind-blown sand causes dunes. Figure 259 shows how a box can be the origin of a dune.

Some dunes remain small, a foot or two high; others rise as high as four hundred feet. The size of the dune depends upon the winds which prevail in the region, upon the character of the soil, and upon the obstacles encountered by the winds. Dunes are not stationary, but are slowly shifted by the winds which blow upon them. If unusually fierce winds arise, the

FIG. 258. — Sand dunes, showing ridges caused by winds.

sand hills are pushed rapidly onward and quickly engulf houses and forests, bury railroad tracks, and destroy travelers.

The shifting of sand and the formation of dunes can be prevented by trees, shrubs, and grasses. Leaves and branches



FIG. 259. — Accumulation of sand about an object which breaks the wind.

shelter sand from the wind, and roots act as nets and hold the sand firm. In Provincetown, Massachusetts, beach grass was

planted on sandy soil to stop the shifting of sand (Fig. 260); and in the dry, sandy regions of Utah and Colorado, poplar trees are grouped around farm buildings and dwellings as a protection against sand storms. A great many plants thrive under desert conditions, and attempts are being made to introduce these plants in regions where there is a danger from advancing and shifting dunes.

Chemical work of the atmosphere. — The oxygen, carbon dioxide, and water vapor that are in the atmosphere cause changes in the appearance and character of building stones, rocks, and soils. Newly built houses soon lose their freshness and become toned down or weathered. Monuments lose their polish and take on a weather-beaten appearance.

FIG. 260. — Beach grass planted to prevent the drifting of sand.

This is because the oxygen, carbon dioxide, and moisture of the atmosphere produce chemical changes in wood, stone, and metal. Many rocks and soils contain iron. Oxygen and water vapor unite with iron and cause rust. A knife blade which rusts acquires a reddish or yellowish color; in the same way the iron which rusts in rock and soil acquires a reddish color.

Many soils and rocks owe their pleasing color to the oxidation or rusting of the iron which they contain. Just as rusty nails slowly crumble and fall to pieces, so rocks, which

rust, slowly crumble and wear away, and their broken bits mingle with the soil and give color to it.

Any process which causes rock to break up and decay is called weathering. Oxygen, carbon dioxide, and water vapor weather rock. Destruction by weathering is a slow process. Well-built houses last for years in spite of weathering, and rocks exposed to the atmosphere change their character and appearance very slowly. When weathering and transportation go hand in hand, erosion results. Water vapor weathers rock, but does not cause erosion because it is powerless to transport to new regions the products of weathering; wind not only weathers rock but also erodes it, blowing away with it the products of its work.

CHAPTER XL

CLIMATE

Environment. — The food we eat, the clothes we wear, the houses we live in, and the work we do, are more or less determined by our geographic environment; that is, by the section of the world in which we live. In the tropics, where it is warm all the time, the natives eat little, wear little, live in crudely constructed houses (Fig. 261), and work sparingly. Because of the climate and the weather conditions, the needs of the people are few, and plants furnishing food, clothing, and shelter are luxurious (Fig. 262). Heavy work is unnecessary, and the people are easy-going, indolent, and improvident.

FIG. 261. — A simple hut made from plants. (Courtesy of Philadelphia Commercial Museum.)

In temperate regions, such as the United States, the temperatures vary from the broiling heat of summer to the icy cold of winter, and variety of food and clothing is needed to meet the changing conditions. The light, dainty meals of summer are insufficient for winter; the thin clothes of August mean

suffering from cold in winter; loosely constructed huts are no protection against winter blasts; vegetation is less luxuriant and lands require more care in order to yield crops equal in size and quality to those of the tropics. Because of the climate

the needs of the people are many and varied. Work must be done to keep abreast of one's needs. People are energetic and thrifty, and activity is seen on all sides; as a result, agriculture flourishes, and trade and commerce advance.

In the cold arctic regions, ice locks up the country most of the year and continued low temperatures hinder all but the most meager vegetation, and force the inhabitants to depend upon hunting and fishing for food and clothing. An abundance

FIG. 262 — Tropical vegetation rich in foods.

of rich fatty food is necessary to supply heat to the body, heavy warm clothing (see frontispiece) is needed to withstand the fierce penetrating cold, and the inhabitants have all they can do to obtain these in sufficient quantity from their bleak barren land. Their food consists of the flesh and blubber of whale, polar bear, seal (Fig. 263), and other northern animals. Their clothing consists of the fur and hides of the

animals. Their shelter in winter is a snow house (Fig. 264) lined with the skins of animals, and in summer a tent made of these same skins. The six months of summer are spent in

*A**B*

FIG. 263. — Arctic animals: *A*, the polar bear; *B*, the seal.

hunting, fishing, sewing furs, and storing away supplies for the six months of intense cold, darkness, and enforced idleness. The inability of the ice-blocked land to support vegetation, the long dark winter, and the inactivity which it creates, keep



FIG. 264. — Life in the arctic regions.

the people from advancing in civilization and taking their place with peoples of temperate climates.

Climate modifies and determines our national and personal habits and characteristics. The most important factors in climate are temperature, moisture, and winds. In order to understand why different parts of the earth have different temperatures, we must know something of the earth and its movements.

The earth and its movements. — The earth is similar to a sphere, but has flattened ends; its shorter diameter is the axis and the ends are the poles. The earth itself is a dark, cold body, but it revolves around the sun and receives light and heat from it. But the earth not only revolves around the sun, it also rotates on its own axis every twenty-four hours. As the earth turns on its axis it presents to the sun first one half of its surface and then the other half; and the side of the earth illuminated by the sun has daylight, while the side turned away from the sun has darkness, or night.

While the earth rotates on its own axis in twenty-four hours, it requires 365 days, or one year, to complete its path, or orbit, around the sun. It does not move in the plane of its orbit in an erect position, but inclined to it at an angle of $23\frac{1}{2}^{\circ}$, with its axis pointed unswervingly to the north star. The daily rotation of the earth on its axis, its yearly revolution around the sun, and its inclination to the orbit, are responsible for day and night, long and short days, winter, summer, spring, and fall in temperate regions, prolonged low temperature in the arctics, and prolonged high temperature in the tropics.

Long and short days. — The sun's rays illuminate one half of the earth's surface at all times. The half on which they shine has day; the other half has night. The margin or edge of the illuminated half is called the circle of illumination, and varies

with the position of the earth in its orbit. On March 21 (Fig. 265), the circle of illumination passes through the north and south poles, and half of the equator and half of every parallel of latitude¹ (Fig. 266) are alternately illuminated and shut off from the sun, and days and nights are equal everywhere. On

FIG. 265. — Position of the northern hemisphere during the year.

June 21, the circle of illumination extends beyond the north pole, but does not reach the south pole; people living in the northern hemisphere have long days and short nights; people living in the southern hemisphere have short days and long nights. In this position of the earth, the north pole is constantly illuminated in spite of the rotation of the earth on its axis, and has perpetual day unbroken by night. The south pole, on the other hand, receives no illumination and has perpetual night.

FIG. 266. — Parallels of latitude and meridians of longitude.

On September 22, the circle of illumination again passes through the poles and day and night are equal everywhere.

¹ A parallel of latitude is an imaginary circle drawn parallel to the equator.

On December 22, the circle of illumination extends beyond the south pole, but does not reach the north pole, and people living in the northern hemisphere have short days and long nights; people living in the southern hemisphere have long days and short nights. In this position of the earth the north pole receives no illumination by day or night and lies in complete darkness; the south pole, on the other hand, is illuminated all the time and has perpetual day.

In the northern hemisphere the days are longest in June and shortest in December; in the southern hemisphere they are shortest in June and longest in December. At the equator, the days and nights are always equal, because the circle of illumination always covers one half of the equator. At the north pole there is a six-month period of perpetual light followed by a six-month period of perpetual darkness; at the south pole just the reverse is true. At the approach of the long periods of darkness in the far north and south, the Eskimos betake themselves to their snow houses, and pass the long winter in idleness and misery. Stefansson in his book *My Life with the Eskimo* gives a wonderful picture of the Eskimos and their intense labors during the long day and their equally intense idleness during the long night.

In temperate regions where there is darkness every twenty-four hours, work and rest are better divided and greater progress in civilization is possible.

Summer and winter. — The amount of heat we receive from the sun depends upon how the rays strike us; the more nearly overhead the sun is, the more heat we receive; the farther the sun is from being overhead, the more slanting are the rays, and the less heat we receive. In December (Fig. 265) the northern hemisphere is turned away from the sun; a portion of it receives rays more slantingly than the southern hemisphere which is turned toward the sun. Because the northern hemisphere

receives little heat it has winter; because the southern hemisphere receives the heat rays straight on its surface it has summer. In June the northern hemisphere is turned toward the sun and the southern is turned away; summer therefore extends over the northern hemisphere and winter over the southern hemisphere.

At the equator the sun is always high in the sky whatever the position of the earth in its orbit, and therefore brings fierce heat to the land; summer exists all the year round. The polar regions are always cold, because the sun's rays always strike them at a very acute angle, and what little heat the rays contribute is absorbed in melting huge masses of ice formed during the long arctic night (Fig. 267). In temperate regions, winter with its short days and long nights changes gradually into spring with equal days and nights; spring in turn changes into summer with long days and short nights; then summer days wane into autumn with days and nights of equal length.

FIG. 267 — An iceberg.

Rainfall. — Heat and rainfall, including both snow and rain, are the most important factors in climate. In certain parts of the state of Washington the rainfall is so heavy that it amounts to over 60 inches or 2 yards a year; in certain parts of Nevada, California, and Arizona the rainfall is so scant that it amounts to less than 10 inches in a year (Fig. 268). We get the exact quantity of rain that falls in a region by placing a straight-sided bucket, or rain gauge, out of doors during rains

and snows, and by measuring the depth of water or melted snow which the vessel catches. The total of all these depths for the year gives the annual rainfall, or precipitation as it is usually called. We know by observation that the states bordering on the Atlantic Ocean and the Gulf of Mexico have abundant rainfall and that most of Nevada, Utah, Arizona, New Mexico, and Wyoming are dry and parched, and have

FIG. 268. — Map showing annual rainfall.

scanty rainfall. The rain gauge gives an accurate measure of rainfall and shows that the rainfall of the first region is 50 inches a year, while that of the second is less than 10 inches a year. The rainfall in the great Mississippi Valley is less than that of the coasts, but is sufficient to support vegetation. A farm or garden needs about 30 inches of rainfall yearly; if it gets this, it yields good crops and is profitable.

Rainfall is usually more abundant along the borders of continents than in their interiors, because border lands are nearer the supply of water. But this is not always true; some lands

situated along oceans and gulfs have scant rainfall. For example, the portions of Lower California which border on the Pacific Ocean are arid and unproductive in spite of their nearness to a vast supply of water. The barren sandy land burned by the hot rays from the sun is warmer than the ocean and does not chill the breezes which blow over it laden with moisture. The winds are heated by the land instead of cooled by it and take moisture away from the dry parched lands instead of giving it to them. In summer the land is warmer than the ocean, and the breezes which blow from it deposit no rain on the land. In winter the land is cooler than the ocean and chills the breezes and receives moisture from condensation.

Winds. — Winds pick up moisture from waters over which they blow and carry it far and wide, depositing it finally as life-giving snow or rain on mountains, plains, and valleys (Fig. 269). Without winds, evaporation of water from lakes, rivers, and oceans would take place so slowly that the air would contain little moisture; and that little moisture would not be distributed far and wide over the land.

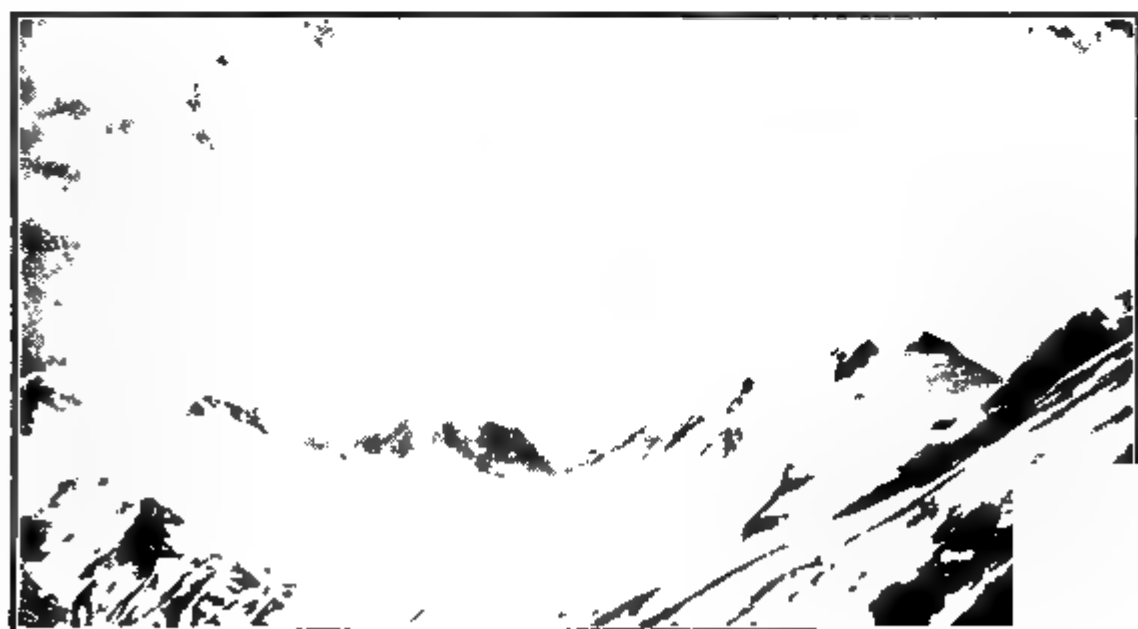


FIG. 269. — New-fallen snow deposited on mountain tops from clouds.

Winds modify the temperature of a region because to a certain extent they carry their temperatures with them. Thus the north wind in general carries cool air southward and lowers the temperature of southern regions and the south wind in general carries warm air northward. Every one living on the coast knows that a breeze blowing in from the sea means a lowering of temperature on the shore. Winds or horizontal movements of the air near the earth are an important factor in climate. Winds affect human beings very greatly. Dead calms are enervating, gentle winds are invigorating. On hot days when no air is stirring, the heat is oppressive and unfits one for hard active work; on days when a gentle breeze or a high wind is astir, the heat, although just as great according to a thermometer, is less oppressive and does not seriously interfere with work.

Winds, as learned on page 27, are caused by differences of temperature in different parts of the earth. The tropics are more strongly heated than temperate regions, and the air over the tropical lands expands and rises and creates a low atmospheric pressure in the region which it leaves. Cooler air from the temperate regions where the pressure is higher rushes into the tropical belt. This cool air is quickly warmed and rises, and its place is in turn taken by cooler air from the temperate regions. In this way permanent air movements or winds are created.

If *A* (Fig. 270) represents the north pole, *E* the temperate areas, *CD* the strongly heated tropical areas, and *B* the south pole, we can trace the path of the outflowing warm winds and the inflowing cold winds. The warm air over the tropical area *CD* is pushed up by the denser cold air which flows in from *EE*. This cold air is warmed and is in turn pushed up by other cold air from the north and the south. In this way there is created a permanent horizontal flow of air toward the poles in the upper atmosphere and a permanent horizontal flow of

air toward the equator in the atmosphere just over the earth. Horizontal movements of air over the surface of the earth are called winds; similar movements in the upper atmosphere are called currents. The winds which blow from *E* to the equator are called trade winds, because their persistency and constancy make them of service to trading vessels.

Much of the air which starts on a poleward journey does not reach the

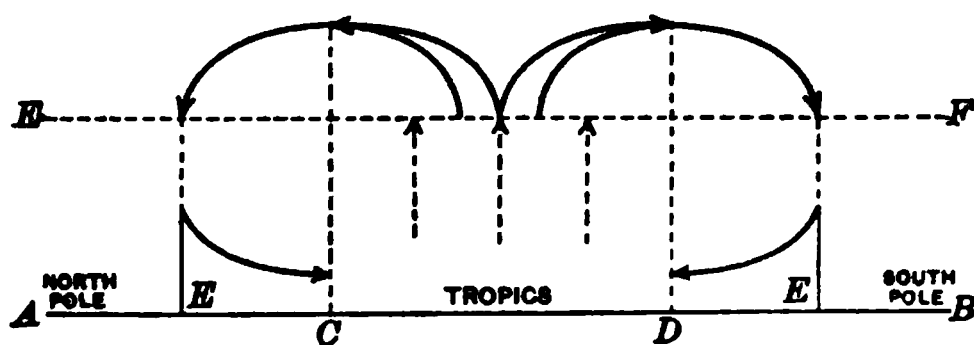


FIG. 270. — Diagram of air currents.

pole, but sinks back to earth when it reaches latitude 25° – 35° , that is, as far north as Florida and South Carolina in the northern hemisphere. This is because it slowly loses its heat and becomes cool and heavy enough to sink to the earth. Roughly speaking, there is a vertical rising of air at the equator, air currents toward the poles in the upper atmosphere, vertical falling of air at 25° – 35° north, and winds toward the equator from north and south.

The direction of the trade winds and air currents is not due north and south, but is obliquely toward the west. This shifting from the true north-and-south direction is caused by the rotation of the earth on its axis.

Other well-recognized winds whose course is not easy to trace are the westerlies, which blow obliquely eastward toward the pole in middle and high latitudes.

In addition to the trade winds and westerlies which flow constantly over the earth, there are irregular variable winds which spring up at different times and places and under different circumstances, such as day and night breezes, mountain and valley breezes, land and sea breezes. Just as breezes may at one time blow from ocean to land and at another time blow from land

to ocean (page 35), so breezes may at one time blow from mountain to valley, at another time from valley to mountain.

Since winds are caused by a variation in the density of air, the greater the difference in temperature between two places, the more rapid is the inrush and outrush of air and the stronger and fiercer and more rapid is the wind. The velocity of wind, or the speed at which it travels, varies from a few miles an hour to 100 or more miles an hour. A light breeze, just sufficient to rustle the leaves of trees, moves from 1 to 5 miles an hour; a breeze strong enough to make whitecaps on the ocean and to sway branches moves from 15 to 20 miles an hour; a gale fierce enough to break branches and blow down fences, or to tear sails from boats, moves 35 to 75 miles an hour; and a hurricane which uproots trees, carries away roofs, and destroys houses moves 100 miles or more an hour.

In many places it is easy to foretell what the weather will be from the direction of the wind. On the Atlantic coast and in most of the eastern part of the United States east winds and southeast winds bring rain; west winds bring clear weather. On the Pacific coast and in the western parts of this country west winds and southwest winds bring rain, and east winds bring clear weather.

CHAPTER XLI

MOUNTAINS, EARTHQUAKES, VOLCANOES, GEYSERS

Mountains.— Since water tends to level down the high places of the earth and to build up the low places, it would seem that the earth ought to be fairly level. But it is not level.

FIG. 271. — Fujiyama, Japan, with an elevation of 12,440 feet above sea level.

Here and there over the world high mountains rear themselves above their surroundings and tower thousands of feet into the sky. Pikes Peak, Colorado, for example, rises 10,000 feet above the surrounding country and nearly three miles above sea level. Throughout Montana, Wyoming, and other western states the giant peaks of the Rockies lift their heads and dominate the landscape; in California the snow-capped Sierra Nevada lift their towering peaks above the sunny plains;

in Oregon and Washington the Cascade Mountains loom up and stand in bold outline against the sky. Sometimes, instead of a number of peaks or a range of mountains, there is only a single peak (Fig. 271). Mt. Hood in Oregon, Mt. Rainier in Washington, and Mt. Shasta in California stand in solitary grandeur unsurrounded by other peaks.

Even higher mountains than those in Washington, Colorado, and California are found in Alaska, Canada, Europe, and Asia. Mt. McKinley in Alaska looms nearly four miles above sea level and Mt. Everest in Asia nearly six miles. In the western part of the United States massive mountains of great elevation are numerous; in the eastern and southern part of the United States, mountains of great beauty but of moderate elevation are found. In New York, for

FIG. 272. — Marble Cañon Plateau, where the Colorado has cut its way through solid rock.

example, there are the Catskills and the Adirondack Mountains; in New Hampshire, the White Mountains; in Pennsylvania, Virginia, and North Carolina, the Blue Ridge Mountains; and in Arkansas, the Ozark Mountains.

Irregular elevations of the earth's crust exist in all lands. If these elevations are more than 2000 feet, they are usually called mountains; if they are less than 2000 feet, they are usually called hills. But this is not always true. The Ozark Mountains are

scarcely 2000 feet above sea level, but they are called mountains because they rise from a low plain. Some elevations in the Rocky Mountains are 3000 feet high, but they are called hills because they do not rise conspicuously above the rugged country which surrounds them.

In addition to the mountains which are scattered over the country there are broad wide elevations called plateaus. The

FIG. 273. — The tops of mountains are generally small in area.

Colorado Cañon Plateau is one of the most famous plateaus in the world (Fig. 272). A plateau is an elevation which has a large area on its summit; a mountain is an elevation which has a small area on its summit (Fig. 273). The expression "mountain peak" comes from the fact that the top of the mountain is peaked or sharper than its base. Plateaus, like mountains, vary greatly in elevation; some, like the Piedmont Plateau east of the Appalachian Mountains, are only a few hundred feet higher than the plain beneath them; others, like the Great

Basin west of the Mississippi, are higher than some mountains. Rivers flow through plateau regions just as they flow through mountainous regions and plains; in fact, a plateau region is usually dissected or crossed by streams, and broken up into hills and valleys and smaller plateaus.

How mountains are made. — Mountains are formed in different ways, but most of them are caused by the warping and folding of the earth's crust, and by upheaval of rock from the earth's interior. Earthquakes give evidence that strong

FIG. 274. — Hard rock is always found below the soil.

forces are at work in the interior of the earth. The forces which cause warping, folding, or upheaval of the earth's crust do not always work in a conspicuous way; more often they work slowly and gradually and almost unnoticed. Forces within the earth are slowly raising the ground around Stockholm, Sweden, 1 foot in 50 years. There is evidence that Mt. St. Elias of Alaska is being raised higher and higher by these internal forces, and there is equally good evidence to show that some coasts are slowly sinking. The forces which cause changes in the earth's crust are not entirely understood, but there is no doubt that they were more powerful in the past than they are to-day.

We know that the crust of the earth is of rock, because if we dig deep enough, we leave soil behind and reach hard rock (Fig. 274). In deep mines, rock extends everywhere and no soil is seen. As a result of some internal force, masses of rock slip and slide upon each other, and cause changes in the land. These changes may be slight, such as those which are taking place at Stockholm to-day, or they may be conspicuous like those which caused great changes in the past. Sometimes the rocks slide in such a way that fissures or cracks (Fig. 275) occur at the surface similar to cracks in a warping board. Sometimes the rocks are displaced or faulted in such a way



FIG. 275. — Earthquake crack.



FIG. 276. — Folded beds of limestone.

that they are compressed against each other and are warped or folded (Fig. 276). Very much as the skin of an apple wrinkles on drying, the earth's crust may wrinkle or fold as a result of

the internal forces. The elevations of the crust are the mountains, the depressions are the valleys.

Not all mountains are due to internal forces; some are caused by forces at work on the surface of the earth, such as water. As we have seen in Chapter XXXVII, water wears away the weak parts of a region and leaves in bold relief the more resistant parts. The Catskill Mountains in New York owe their

FIG. 277. — The results of an earthquake.

existence to the fact that the weaker rocks of the region were eroded by water, while other rocks withstood erosion. Pikes Peak, Colorado, is another illustration of rocky land which has become a mountain because of the wearing away of weak rocks.

Earthquakes. — The present-day movements of the earth's crust are usually slight and attract no attention. The deep underground rocks slip and slide such small distances that only faint tremblings or quakes result on the surface. But occasion-

ally a movement of sufficient force occurs to produce serious tremblings or quakes at the surface. This is the dreaded earthquake. The serious San Francisco earthquake of 1906 was caused by a considerable movement of the deep underground rocks in that region. The rocks for miles moved as much as 5 to 15 feet horizontally. Such internal changes inevitably caused movement at the earth's surface and led to serious disaster. Buildings were overthrown, bridges and railroads were wrecked, crops were devastated, many lives were lost, and thousands of people were made homeless (Fig. 277). A severe earthquake occurred in Chili in 1822; after the earthquake it was found that the land had been raised about 3 feet. Earthquakes are more numerous in some regions than in others. Italy has suffered greatly from them. The United States is fortunate in having had few violent earthquakes in the past. Next to the San Francisco disaster, the most serious earthquake in this country was that which occurred at Charleston, S. C., in 1886.

Sometimes earthquakes take place at the bottom of the sea. These earthquakes cause such violent disturbances of the water that vast waves surge out from the area, and overwhelm ships, and traveling shoreward engulf towns and villages. Italy, Portugal, and Alaska have experienced such disasters.

Volcanoes.—Volcanoes are among the most striking phenomena of nature. They are usually cone-shaped (Fig.

FIG. 278. — Diagram of a volcano.

278), and from an opening called a crater they pour forth at irregular intervals molten rock, solid rock fragments, hot gases, and vapors. Sometimes the molten rock, or lava, streams out quietly; sometimes there is a violent eruption and large pieces of rock,

small fragments of rock called volcanic ash or dust, gases, and vapor are hurled out. The outstreaming lava flows around the crater and on cooling solidifies and builds up into a gently sloping mound or cone. Some of the rock frag-

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FIG. 279. — Mt. Lassen in eruption.

ments also fall around the crater and help to build up the cone. The smallest rock fragments are hurled far into the air, where they are caught by the winds and carried long distances. The hot gases and vapor are also blown far and wide, and some

of the poisonous ones carry death to the regions over which they pass.

Volcanoes are dangerous and destructive. Mt. Vesuvius, Italy, in one eruption threw out enough cinders and ashes to bury the city of Pompeii completely. So great was the discharge of the volcano that the city was covered by a 20-foot blanket of cinders and ashes, and was completely lost to view. Not until centuries later was the volcanic mass dug away, and the ruined city brought to light. Volcanoes are not constantly active; sometimes they are quiet for years, or throw

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FIG. 280. — Mt. Shasta. These mountains were once active volcanoes.

out so little matter that they cause no real damage. Mt. Vesuvius has periods of rest and quiet eruption followed by periods of violent action. One of the worst eruptions of Mt. Vesuvius was in April, 1906, when thousands of people were destroyed by the hot matter which was thrown out over the country.

Until 1914 the United States was thought to be free of active volcanoes because, since the white man had known America, no volcanic outbursts had taken place. But in 1914, Mt. Lassen in California began erupting, and since that time has continued to erupt at frequent intervals (Fig. 279). The eruption which took place on March 21, 1915, was the eighty-third eruption

since the beginning of the volcanic activity less than two years before.

How volcanic cones form. — In the beginning, a volcano is simply a weak place or vent in the earth's surface through which hot matter is ejected. With each eruption the land around the vent or crater builds up and takes the form of a mound or cone. The crater rises higher and higher above its original position and finally becomes the summit of a high

FIG. 281. — Lava streams.

mound or a high hill, or even a mountain. The crater of Mt. Vesuvius has been built up until it is now about 4000 feet high. From the crater an opening runs down into the earth and affords a channel for the escape of the hot lava. In some of the large volcanoes the craters are more than a mile wide, in the smaller ones the craters are only a few hundred feet in size. From these craters enormous masses of matter are emitted and build up massive volcanic cones.

In time all volcanoes cease to be active. Lava ceases to flow. The crater fills up and the destructive volcano becomes a harmless mountain. Many extinct or inactive volcanoes exist in the United States; Mt. Hood, Mt. Shasta (Fig. 280), and Mt. Rainier were at one time active volcanoes. To-day they are among the most beautiful of our mountains. So high are these one-time volcanoes that the snow and ice never disappear from their summits. On their lower slopes rich forests thrive and beautiful flowers grow in abundance.

The lava and rock fragments thrown out from an active volcano may spread many miles from the vent and build up land. Very often a volcano has more than one crater, and lava frequently streams forth (Fig. 281) through weak places along the sides of the volcano as well as from the crater. Volcanoes, because of the matter which they erupt, have an important effect on a region. They build up mountain slopes, or they raise the general level of the land on which their erupted matter falls. As a result of volcanoes in the Pacific Ocean, several new islands have been formed in recent years.

Hot springs and geysers. —

The surface of the earth is cold, but its interior is hot. Men cannot work in the deep mines

FIG. 282. — A geyser in Yellowstone Park.

unless cold air is pumped down to lessen the heat. Hot water bubbles out of the ground in various places, showing that it has

passed through warm regions and been heated. The Hot Springs of Arkansas and the geysers of Yellowstone Park tell us very plainly that the earth's interior is hot. Volcanoes with their molten lava and burning cinders tell the same story. The most wonderful hot springs of the United States are in Yellowstone Park. In some of these springs the water is boiling hot, and is so abundant that it forms large ponds. The geysers of Yellowstone Park (Fig. 282) are simply spouting springs; Old Faithful Geyser, for example, throws out hundreds of barrels of water every hour to a height of 150 feet. But few geysers erupt as regularly as Old Faithful.

Earthquakes, volcanoes, and geysers are evidence that the earth's interior is not at rest, but is constantly changing. The forces at work within the earth and those at work on the surface alter the character of the land and keep it from becoming a flat monotonous plain.

CHAPTER XLII

THE ROCKS AND BUILDING STONES OF THE EARTH

Granite. — Lava does not all find an outlet to the earth's surface through volcanic vents. Large quantities of it never reach the surface, but harden underground in cracks and fissures and form underground rock. Sometimes lava in its effort to escape uplifts the overlying rock, and creates an elevation beneath which it slowly cools and solidifies. Lava upon solidifying becomes igneous rock. The character of this rock depends upon the parent lava and the conditions under which it solidified.

Granite, an igneous rock, is close

FIG. 283. — Obsidian cliff, Yellowstone Park.

and hard, granular in structure, and usually of a reddish or grayish color. Obsidian (Fig. 283), another igneous rock, is solid, but glassy in character and black in color. Pumice, still another igneous rock, is a very light-weight, porous rock, full of minute air spaces.

For building purposes granite is the most important of the igneous or lava-formed rocks. It is so strong and compact that it can endure enormous strain, and it is not easily weathered. Granite structures are among the most durable known. But the hardness and compactness which make granite valuable as a building stone also make it expensive, because it is hard to split and dress. Granite is quarried abundantly throughout the United States, particularly in the East.

Sandstone.—This important building stone is simply a mass of tiny grains of sand cemented together into a firm solid rock. It is formed from the sediment deposited by running water, and for this reason is called sedimentary rock. Sedimentary rock is sometimes called stratified rock, because the de-

FIG. 284. — Stratified rock.

posits of which it is composed are frequently in the form of layers (Fig. 284). Limestone is a sedimentary rock, because it is formed from the vast deposits of decaying shells which accumulate at the bottom of rivers and oceans, or from the deposits

of lime left by running water. Sedimentary rocks are very abundant and form about four fifths of all the rocks of the earth.

There are various kinds of sedimentary rock just as there are various kinds of igneous rock. Sandstone is one of the most popular for building stone. It is abundant, easy to quarry, and easy to dress. The red sandstone of Pennsylvania is particularly popular and is used extensively, especially in the eastern part of the United States. The objection to sandstone for building purposes is that it is soft and porous and easily weathered. Buildings made of the very soft sandstone look old in a few years.

Marble. — In the course of time, igneous rock and sedimentary rock may lose their characteristics and become modified into

FIG. 285. — A quarry of metamorphic rock.

new forms of rock. Lava which cooled underground may become exposed to the atmosphere, and so lose its original characteristics and become greatly modified in composition and texture. Lava which cooled on the surface may become buried

and modified by its new underground conditions. Not only igneous rocks, but also sedimentary rocks are modified by con-

FIG. 286. — Quarrying for marble. (Courtesy of Philadelphia Commercial Museum.)

ditions, and may lose their original composition. Igneous and sedimentary rock which have been altered in character in any way are known as metamorphic rock (Fig. 285).

Marble is a metamorphic rock formed from limestone by pressure of overlying rock and by the internal heat of the earth. Marble may be white or colored, according to the limestone from which it is formed (Fig. 286). It is one of the most beautiful and highly prized of the building stones, but because of its scarcity and cost, it is used mainly for ornamental purposes. Marble does not weather so easily as sandstone, but it weathers more quickly than granite. The chief source of marble in the United States is Vermont.

Mortar, cement, and concrete. — Rocks could not be used satisfactorily for building purposes unless there were some substance to fasten them firmly together. The stones of a house would be loose and unstable unless united by mortar or cement. Mortar is made from limestone which is broken up into large lumps, and heated for hours in strong kilns (Fig. 287). Under the action of intense heat, the limestone changes to quicklime or unslaked lime. The quicklime is packed in barrels and kept in a dry place. When ready to be used for mortar, it is mixed with enough water to make it a thick paste, and into this thick paste sand is slowly stirred.

Limestone is also used in the making of cement. When heated with clay or other substances, it forms the cement which

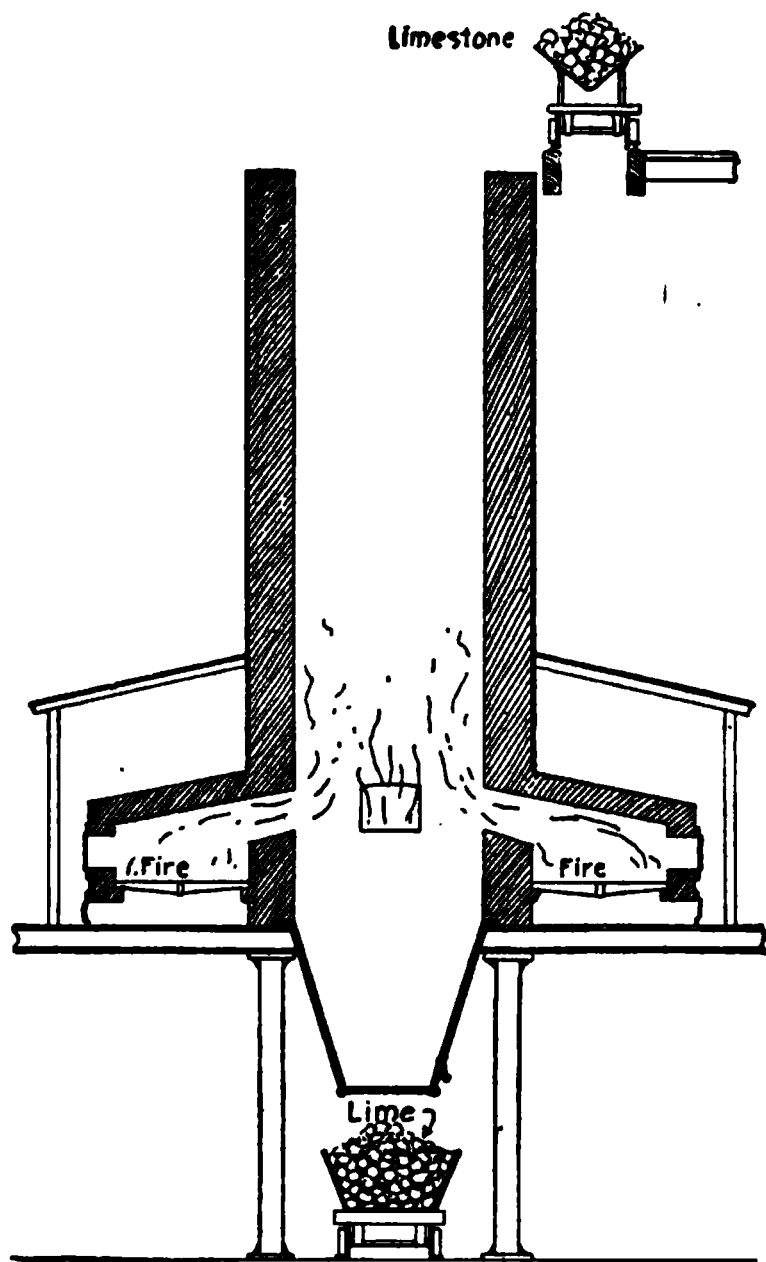


FIG. 287. — A lime kiln.

is widely used for pavements, linings of reservoirs, and flooring of stables and dairies. Cement has added greatly to the cleanliness and to the safety of the world. Cement floors and trimmings can be more thoroughly and more easily cleaned than wooden floors and trimmings and are safe from fire.

Cement is expensive and cannot be used alone for the construction of buildings. Its place for that purpose is taken by concrete, which is simply a mixture of cement, sand, gravel, and water. Concrete is not only reasonably cheap, but it is also easy to handle. This is largely because it takes the form of the mold into which it is poured and quickly sets or hardens. Concrete has greatly simplified the construction of underwater structures. For example, if an underwater concrete column for a bridge is to be erected, a hollow wooden mold is sunk into the water and concrete is poured into it. The concrete displaces the water and fills the mold, where it quickly hardens. The mold is withdrawn and the concrete support is finished.

Concrete is often strengthened or reënforced by metal forms placed within the molds. The concrete hardens around the metal supports as around a core, and forms a strong durable structure.

CHAPTER XLIII

PLANTS AND THEIR RELATION TO MAN

THE stone quarried for buildings, the metal smelted for utensils, and the coal mined for heat are important products of the earth; but the plants which grow in the deep soil mantle are the most important of all the products because without them man would have no food to sustain him and would be unable to

FIG. 288. — An apple tree in blossom.

use stone, metal, and coal. Most plants have roots, stems, and leaves, and in addition bear conspicuous flowers (Fig. 288) and fruits sometime during the year. The violet plant bears flowers in early spring, the nasturtium plant in the summer, and the aster plant in the late fall; strawberry vines bear

fruits in the spring, the chestnut trees ripen their fruits in the autumn. Flowers and fruits are intimately connected because the fruit is the outgrowth of the flower. The plant which fails to produce flowers fails also to produce fruit; the plant which produces poor flowers produces also poor fruit. Some flowers

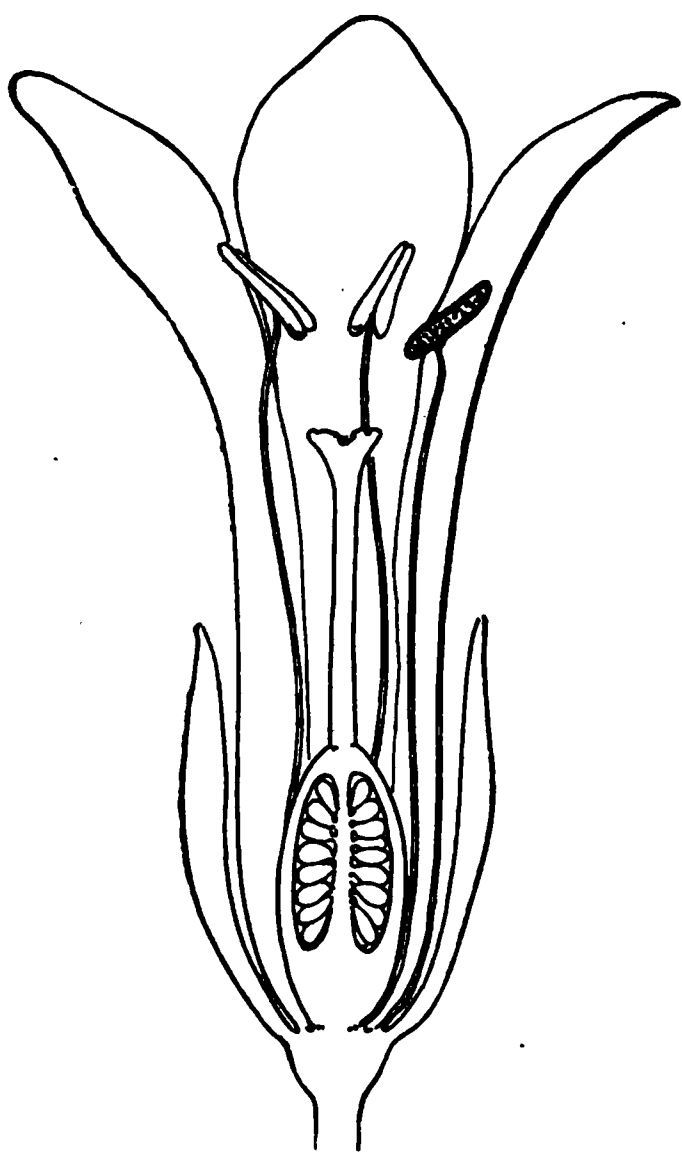


FIG. 289. — A flower cut lengthwise to show calyx, corolla, stamens, and pistil.

develop into luscious, juicy fruits, like apples, pears, peaches; others into hard fruits, like grains of wheat and nuts of the pecan tree. Some flowers develop into inedible fruits, like the acorns of the oak tree and the papery keys of the maple tree.

The structure of a flower. —

When we examine a flower such as a buttercup, we find on the outside of it a circle of small green leaves. The circle of leaves is called the calyx and the separate leaves are called sepals. The sepals are of great service to the young unopened flower, because they protect it from cold, rain, and wind, and from insect enemies.

Next to the calyx is a circle of colored leaves, called the corolla, the separate leaves of which are called petals (Fig. 289).

Next to the petals are the stamens, threadlike bodies with knobs on their ends. The slender stalk of the stamen is called the filament, and the enlarged end is called the anther. The anther is really a box or sac which contains minute powdery grains called pollen. Before the flower is in full blossom the anther sac is closed and the pollen grains are protected. When

the flower is in full blossom the anther sacs open and the pollen grains are exposed. Occasionally pollen is so abundant that it brushes off on the nose when we smell the flower, or it falls on the table and makes a faint dust when we arrange a bouquet.

In the center of the flower is the pistil (Figs. 289 and 290), having a swollen base, the ovary, and a broadened tip, the stigma. The ovary is connected with the stigma by a stalk called the style. The stigma is usually covered with a sticky fluid, to which dust and pollen adhere readily. When we open an ovary, we see that it contains tiny seedlike bodies, called ovules. It is the ovary of the flower which develops into fruit, and the ovules which develop into seeds.

The growth of the flower into fruit. — Seed cannot form and fruit cannot develop unless pollen from an anther falls on the stigma of a similar flower. A cherry cannot form unless the pollen from a cherry blossom falls on the stigma of a cherry blossom; a cucumber cannot form unless the pollen from a cucumber blossom falls on the stigma of a cucumber blossom.

FIG. 290. — A flower from which the pistil protrudes.

As soon as pollen grains of the right sort fall on a stigma they begin to grow and to send delicate threadlike tubes down through the style to the ovary. The delicate threads enter the ovary, and when they reach the ovules, they burst and discharge a mass of matter. The ovules unite with the discharged matter and are said to be fertilized. The fertilized ovules begin to grow and to require more space, and the ovary wall swells and enlarges in order to accommodate them. In time the swollen ovary becomes a ripened fruit, and the enlarged ovules become ripened seeds. Some fruits, like the cherry, contain only one seed;

others, like the tomato, contain many seeds. Sometimes the enlarged ovary wall is soft and juicy, as in the cherry; sometimes it is hard and dry, as in the walnut.

The pollen travels from flower to flower. — Pollen grains which fall on the stigmas of their own flowers develop poor seeds or no seeds at all. Seeds are the offspring of two parents, and in order to obtain seeds of the finest grade, the two parents must belong to different flowers; that is, the pollen which falls on the stigma of one flower must be pollen from another flower.

Just as the wind blows dust through the air, it blows pollen. It lifts the light powdery pollen grains from the anthers and carries them until they settle on flowers, on leaves, and on fences. Pollen that settles on leaves and fences is wasted, but pollen which chances to rest on a flower like that from which it came makes its way to the ovules and unites with them to form seeds.

But wind does not have access to the pollen of all blossoms. In many flowers the stamens are inclosed by the petals and the

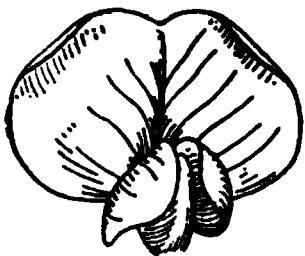


FIG. 291. — The sweet pea.

wind cannot reach their pollen. This is true of the sweet pea (Fig. 291), where the petals are keel-shaped and shield the stamens. Bees force their way into the closed corolla in search of nectar and rub pollen on their hairy bodies as they brush against the anthers. When the bee rests on another sweet pea, it rubs against the stigma and deposits on it some of the pollen brushed from the first flower. When flowers have sticky or protected pollen, they are entirely dependent upon insects and birds for the transfer of pollen.

The pollen of the clover plant is distributed by the bees and unless the fragrant blossoms are visited by these busy insects, seeds do not develop. Some years ago the Australians imported clover seed and attempted to raise clover as fodder for

their cattle. They succeeded in growing beautiful fields of flowers the first year, but no fruit from which seed could be harvested for the next year's crop. The farmers found it expensive to import new clover seeds every year, and inquired of the European farmers what caused their seeds to ripen. As a result of an investigation, it was found that the bumblebee pollinated the clover plant. The Australians immediately imported bumblebees, and have since had no difficulty in getting seeds for their future crops.

New and fancy fruits. — The seed is the result of pollen and ovules from two parents, and the plant which grows from the seed usually has some of the characteristics of both parents. If pollen from a peach blossom is forced to grow on the stigma of a plum blossom, fruit and seed will develop. But when the seeds thus formed from a peach parent and a plum parent are planted, they grow into plants bearing fruits which are like and yet unlike the fruits of their parents.

Fancy fruit growers originate new kinds of fruits by artificially pollinating flowers with pollen unlike their own. They open flower buds, remove the anthers with their pollen, and then tie bags around the flowers in order to protect them against pollen carried by wind and insects. They now remove pollen from another flower which they wish for a parent, open the bag, and spread the pollen over the stigma. The unusual pollen grains are the only ones on the stigma, and having no rivals, they develop. In time fruit and seed form, and the seeds grow into plants which differ from both parents, but which show some of the characteristics of each.

Apricot and plum blossoms have been cross-pollinated by Luther Burbank and have given rise to a new fruit, the plumcot. Potato and tomato blossoms were crossed by the same worker and gave rise to another new fruit, the pomato. When plants of different kinds are thus cross-pollinated, the result is known as

a *hybrid*; when different varieties of the same fruit are crossed, such as red apples and green apples, the result is known as a *cross*. Hybridization and crossing enable us to obtain many new varieties of fruit, and to improve those varieties which we already have. Sometimes it is possible to obtain plants which

FIG. 292. — The middle flower is a hybrid between a red and a white carnation, showing characteristics of each parent. (After Andrews.)

have many of the good characteristics of both parents and none of the objectionable characteristics of either. Fruit sellers say that red apples because of their attractive color bring the highest prices, and hence they are constantly on the alert for apples of this color. Because of this demand, fruit growers strive to increase the varieties of red apples, and generally use red apples as one parent in hybridization. Every day efforts

are being made to improve the numerous fruits and flowers which we already have, and to add to their numbers others of equal value (Fig. 292).

The plant's need of seeds. — Nature depends largely upon seeds for her future crop. The seeds which fall from the solitary

FIG. 293. — Young cedars springing up around the parent tree.

cedar tree take root, grow, and in time may transform the field into a thick forest (Fig. 293). The seeds of the maple tree are dainty and light and are blown about by the wind, and some of them fall to the ground far away from the parent plant (Fig. 294). The seeds of the milkweed plant (Fig. 295) have silky hairs attached to them which act as sails in the wind and carry the seeds far and wide. Seeds are frequently taken from field to field by animals which carry them on their rough or shaggy coats (Fig. 296). Every

FIG. 294. — Maple seeds.

seed which falls to the ground under good conditions develops into a plant and thus keeps on the earth the type of plant from which it came.

Some plants grow only from seeds and would disappear from the earth if they failed to produce seeds for future plants. Other plants, like the iris and wild ginger, are

FIG. 295. — The silky hairs act as sails for the milkweed seeds.

not entirely dependent upon seeds for future growth because they possess a hardy rootstock which survives the winter and sends up new shoots in the spring. Still other plants, like the lily, hyacinth, and onion, produce bulbs which remain alive after the rest of the plant has died, and which develop into flourishing plants the following season (Fig. 297).

The survival of the fittest. — Seeds do not all develop into mature plants. The milkweed

seeds, for example, which are carried far and wide by the wind do not all become mature plants. Some of them settle in barren places where their roots cannot get a foothold; or drift into ponds and streams where they die; or fall among stronger plants which choke them and crowd them out. Some seeds are eaten by birds, squirrels, and other animals, and some are



B

FIG. 296. — A, cocklebur; B, burdock.

dried up by the fierce summer sun, or bitten by frost, and are therefore not awakened to life by the spring rains.

The chances are often small that a seed will fall into a safe place and will be free from enemies. Although so many seeds are destroyed, the average plant produces such large numbers of them that enough survive to produce a growth of new plants. A healthy fox-glove plant produces over one million seeds, so that even with heavy losses, enough seeds remain to guarantee plants in abundance.

The worst enemies of sprouting seeds and growing plants are overcrowding and starvation. A plant needs water, air, food, and plenty of room. The seeds and young plants which start their growth in crowded places are too overshadowed by their close neighbors, too shut off from air and sunshine, and too meagerly supplied with food

FIG. 297. — Lily bulb.

from the ground to develop into healthy plants. Some seeds are stronger than others and can get a start in spite of overcrowding, of burning sun or bitter cold, of too dry soil or too wet soil or too little soil (Fig. 298). Plants which come from hardy seeds usually grow in spite of unfavorable con-

FIG. 298. — These plants are growing in spite of unfavorable conditions.

ditions and develop into fine plants, crowding out the weaker ones that have developed from poor seed. The survival of strong, hardy plants is known as the survival of the fittest.

Selecting seeds. — Good plants come from good seeds, and if we wish hardy, healthy, crop-bearing plants, we must sow seeds which have come from strong, vigorous plants. If seeds are yearly selected from plants which yield the best and largest crop, there will be a steady improvement in the size and quality of the harvest, and a distinct gain to the grower (Fig. 299).

FIG. 299. — Good clover seed.

Poor clover seed

By careful selection of seed we are able not only to improve the quality and quantity of the crop, but also to secure other results of commercial value. The peas which are earliest in the market bring higher prices than those which come later in the season, and hence growers make strenuous attempts to obtain early peas. They sow seeds from the plants which ripened peas the earliest, and by following this practice year after year, they finally obtain plants which grow in colder weather and ripen their fruit much earlier than the average.

The fibers of the stem of the flax plant are woven into linen materials and the longest fibers are of the greatest commercial value. In order to increase the height of the stem and the length of the fibers running through it, seeds are picked only from the plants having the longest stems. As a result of careful

selection of seed from plants taller than their neighbors, the length of the fibers has been gradually but steadily increased.

Wheat is a paying crop and is so much in demand for flour and cereals that attempts have been made to grow it in many different climates. But grains of wheat which will yield a magnificent crop in warmer regions are killed by the rigors of the northern winter. In order to obtain plants which will grow in the cold regions of northern Canada, for example, it was necessary to select seeds from plants which best endured cold weather, and as a result seeds have been obtained which develop into plants capable of enduring intense cold.

By artificial pollination and by selection of seeds, we are constantly changing the nature of the plants around us, and are replacing those

which are less desirable by those which are more desirable (Fig. 300).

FIG. 300. — 1, Wild gooseberry; 2, improved by selection. (After Andrews.)

Cultivated plants. — In earliest times man secured his food from wild crops, choosing from the multitude of plants those which best suited his individual taste. Many of the wild plants, like the thistle, furnished nothing which he cared to eat; others, like the wild cherry tree, furnished fruit which remained good

for only a short time; and still others, like the wheat plant, furnished grain which could be kept for months and used during the long winter when fresh plant food was scarce.

In order to increase the harvest of the plant which he liked, and to have crops in places convenient to his dwelling, man began the artificial growing of plants. Seeds from the desired plants were sown in definite plots of land. Soon it was learned that the abundance of the crops depended upon rainfall, upon the fertility of the soil, upon plowing, upon weeding, and upon many other factors. As a result, more and more attention was

given to the cultivation of plants. Richer fields were sought in which to plant seeds, and deeper plowing and more careful weeding were done.

The wild plants improved under the altered conditions, but it was many years before they became transformed into the garden plants of to-day. The close tender head of cabbage with its many leaves

FIG 301.—The wild pear tree is very hardy and may develop into a valuable tree under cultivation.

came from a simple wild plant having only a few bitter leaves arranged in a loose cluster; but it took years to accomplish the change. Soft, sweet, juicy corn came from stalks bearing small ears of hard dry kernels; but for this, also, years of work were necessary. Artificial pollination, selection of seed, and cultivation enable us to change totally the character of plants, and to

make out of apparently useless weeds, cultivated plants of great value (Fig. 301). At present the milkweed plant is a pest to farmers, springing up everywhere and crowding out better plants. But it is thought that a valuable plant may be developed from the weed, because on its seeds are fine hairs which may possibly be strengthened and lengthened, and ultimately be made to rival cotton and flax fibers.

The awakening of the dormant seed. — The seeds which fall to the earth in autumn lie dormant until the first warm days of spring. Then they begin to grow; that is, they sprout and germinate. The seeds which fall in the hot, dry, desert sands lie dormant until a soft, gentle rain comes. Then under the influence of warmth and moisture they rapidly develop into tiny plants. Common observation teaches us that warmth and moisture are necessary to awaken seeds and to start them in their growth. If seeds are kept moist but lack heat, they rot and are useless. The farmer who sows his crop in the early spring dreads a cold “snap” because he knows that many of his seeds will not develop for lack of warmth, but will rot in the moist earth. Seeds do not all require the same amount of warmth. Early pea, lettuce, and radish seeds develop in fairly cold weather, because they require only a small amount of warmth. Corn, squash, and onion seeds do not develop so early in the spring, because they need more warmth. If you have a garden, you know very well that you should plant some seeds as early as March, others not until April, and still others not until May.

Even in the warm summer days seeds do not develop if they lack moisture. But after a warm rain tiny shoots are seen springing up everywhere over the ground, the seeds from which they came having been awakened into life and activity by warmth and moisture. But although warmth and moisture are necessary to awaken a seed to growth, they are not all that is necessary because in addition to heat and moisture, there

must be a goodly supply of fresh air for the seeds. If a field in which seeds have just been planted is trampled on so that the ground is packed down, the seeds do not sprout. This is because air cannot penetrate between the particles of packed soil, and without air seeds cannot respond to heat and moisture. The farmer plows and harrows his fields before planting seed in order to loosen the soil and to

FIG. 302. — Harrowing loosens the soil.

make new channels through which the air can penetrate (Fig. 302). The earthworm is helpful to the farmer because in winding its way through the soil, it leaves openings through which the air can reach the seeds.

A large part of the moisture which the seed needs for germination soaks through the seed coat, but some makes its way to the embryo through a small pinlike opening near the scar on the seed (Fig. 303). The soil must be packed close around the seed in order that the seed coat and opening may take moisture from it, but the soil must be packed loosely enough to admit the air necessary for growth and germination.

Food for the seedling. — Food is necessary to start the seed in its growth, and the food which the embryo plant needs to start its growth is stored in the seed. In the bean the thick swollen cotyledons, or halves of the seed, contain food (Fig. 304), which supplies the seedling until it is ready to forage for itself. The food

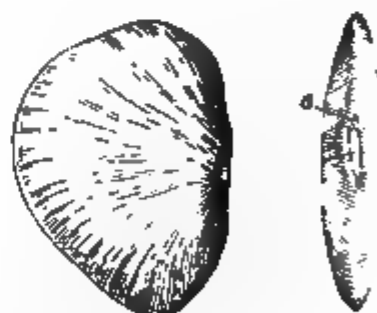


FIG. 303. — A bean, showing opening *a*.

within the seed was made by the plant which bore it, and was stored there for the use of the seed during germination. The chief foods prepared by the parent plant and stored in seeds for the benefit of the growing embryo are: oils, starch, protein, and mineral matter. Some seeds contain all these foods, but most seeds contain a conspicuous quantity of only one food. For example, in cotton and flax, and in the seeds of peanuts and Brazil nuts, oil is the principal food; in corn and wheat, starch is the principal food substance; in peas and beans, proteins take the leading place.



FIG. 304. — A bean with one cotyledon removed.

From seedling to plant. — To observe the development of the embryo into the seedling, place moist blotting paper in a dish and lay on it some soaked bean seeds. Within a few days the seed coat is pierced by a slender organ which rapidly grows into a root; finally the seed coat is quite torn, and growing stem and bud force their way out and grow upward. When we watch the bean seedling carefully, we see that it develops at the expense of the cotyledons, the seedling becoming larger and stronger as the cotyledons become more and more shriveled. As long as any food remains in the seed the seedling thrives, but when the food supply is exhausted, the seedling droops and dies. If the seedling is to continue its growth, it must be placed in the soil and begin its work of food getting. As soon as the plant is in the soil, its root increases in size

FIG. 305. — Roots of clover.

and sends off numerous branches which grow and spread farther and farther through the soil (Fig. 305). The stem also grows rapidly, pushes its way upward, and develops numerous leaves.

The soil as a source of plant food.—Plants, like other living organisms, require food for existence and growth, and they obtain food from two sources, the soil and the air. From the soil the roots take water containing dissolved mineral and organic matter. The soil water absorbed by the root rises through the stem and makes its way to all parts of the plant. The leaves take carbon dioxide from the air. The carbon dioxide combines with the water and forms starch and sugar. Both soil food and air food are essential to plant life, because if either is lacking, the plant droops and dies. If the farm soil is poor and lacks plant nourishment, the crops starve. The wise farmer always keeps his soil rich in plant foods by fertilizer, that is, he puts into the soil substances which he knows the plant needs.

How soil food gets into the plant.—The soil is a storehouse of water and food for the plant. Water, holding dissolved soil food, enters the plant not through the roots, but through small hairs called root hairs. The delicate root hairs grow only on the tender young roots or rootlets, a short distance back from their tips (Fig. 306). When the rootlets grow into roots, they lose their root hairs, but they send off new rootlets on which root hairs quickly form. The root hairs absorb moisture through their thin delicate walls. A transplanted bush wilts and droops for a long time, because no matter how carefully it is removed from the soil, some of its rootlets are torn off or injured and the water and food supply are lessened. As soon as new rootlets and new root hairs develop on the trans-

FIG. 306. — Root hairs (*R.H.*) on sprouting corn.

planted bush, the work of food getting begins, the food supply is increased, and the new plant revives and renews its growth.

How the root hairs feed. — When we examine a root hair, we find that it contains no visible pores through which water can enter. We know that water does pass through the root hairs, however, and a simple experiment will show how it enters. Fasten a soaked membrane, such as the bladder of a fish, or the skin of sausage, to the broad end of a thistle tube, and fill the bulb with sirup. Support the thistle tube in a jar of water in such a way that the sirup within the thistle tube is on a level with the water in the jar. (See Fig. 307.) In a few hours the sirup in the thistle tube rises above the level of the water outside. Water from the jar has passed through the membrane and has made a place for itself in the narrow tube. If the experiment is left standing for a long time, a little sirup may pass through the membrane into the water, but the amount is extremely small. The passage of liquids from one side of a membrane to the other is called osmosis.

FIG. 307. — An experiment to illustrate osmosis.

Root hairs contain sap, a liquid which is denser than the soil water which surrounds them. The water passes by osmosis through the delicate walls of the root hairs and becomes a part of the plant.

The working plant. — The nourishment stored in the seed by the parent plant is just sufficient to give the seedling a start

in life. As soon as the stored food is exhausted, the plant must work for itself and secure its own food. The only sources from which a plant can secure food are the soil and the air. The mighty forest trees with their enormous trunks, massive branches, and numerous leaves, as well as the tender young blades of grass, owe their existence to soil food and air food.

When we examine plants carefully, we find that they contain carbon. The framework of the plant, the gum of the stem, the sugar of the trunk, the starch of the grains, the oil of the nuts, the fibers and spices, etc., are largely carbon. We know that the soil does not furnish the carbon found in the plant, hence we conclude that the air furnishes it. The air does not furnish pure carbon to the plant, but it does furnish carbon dioxide. The plant takes the carbon dioxide from the air and separates it into carbon and oxygen. It combines the carbon obtained from the carbon dioxide with the water absorbed through the roots, and from the combination makes starch and sugar.

The foods manufactured by the plant from the substances gathered from the air and soil dissolve in cell sap and are carried by it to all parts of the plant. Sometimes more food is manufactured than is needed for immediate use. The surplus food then accumulates in roots and stems for the future use of the plant. A surplus of sugar is stored in the beet and sweet potato root. A surplus of starch is stored in underground swellings of the white potato. Asparagus, carrots, rhubarb, all contain a good supply of surplus food. Because plants accumulate surplus food, man is able to utilize them.

How the plant secures carbon dioxide. — An acre of fast-growing banana plants requires about eight tons of carbon each year, and an acre of slow-growing beech trees requires about one ton of carbon each year. When we consider the multitude of plants which are scattered throughout the land, the large forest trees, the luxurious tropical ferns, the waving prairie grains,

the green meadow grasses, the cultivated fruits and vegetables, we realize that the amount of carbon dioxide used by them is enormous. This supply comes partly from the breath of people, and partly from creatures, which, like birds, fly through the air, or, like cattle, roam over the surface, or, like worms, burrow in the soil. Everything that breathes, whether it be plant or animal, large or small, sends out carbon dioxide into the air, and is a source of food to plants. Decaying matter gives off carbon dioxide, and the decaying grasses of meadows, the rotting fruits of orchards, the decaying leaves and tree stumps of forests are sources of carbon dioxide. Carbon dioxide also comes from smoldering logs and burning fuel. The carbon dioxide given out by breathing organisms, by burning substances and decaying matter is caught up by the wind, and is scattered far and wide over the land. So much of this carbon dioxide is removed from the air by the plants, that ordinary fresh air contains only about .04 per cent of it. The air of a city or town is never quite as free from carbon dioxide as is the air of the open village and country.

A working plant needs light and chlorophyll. — Plants grown out of doors or in bright rooms are healthier than those grown in dark and ill-lighted places. In our homes we place the winter plants near the windows, knowing that they grow faster and stronger and keep fresher and greener there than in a more shaded position. Unless a plant has light, it starves to death, because without light a plant cannot combine soil water and carbon dioxide into food substances, such as starch and sugar. Unless a plant receives light, its leaves turn yellow (Fig. 308) and fall off, and it dies. In order to be strong and independent, a plant must have in its leaves a substance called leaf green, or chlorophyll, and leaf green cannot form unless light shines upon the leaf. But a plant does not necessarily

have leaf green because it lives in a good light. Indian Pipe, or Nun-of-the-Woods, often grows in the ground side by side with arbutus and violets. It never has any leaf green, no matter how good the light, while arbutus and violets always have it. It is known from observation that a plant must

have both leaf green and light in order to make food for itself from soil water and carbon dioxide. "Beech drops" cannot make their own food even though bright sunlight shines upon them, because this plant always lacks chlorophyll. The whitish waxy Indian Pipes scattered through the dried leaves of the forest cannot make food for themselves because they too lack leaf green. Plants without leaf green send piercing roots into neighboring plants, and steal from them the food manufactured

FIG. 308. — If a strip of black paper is laid across a leaf, it excludes sunlight and turns the shaded part yellow.

for their own use. Such plants are called parasites. Sometimes plants which lack leaf green live upon decaying logs and rotting leaves. They are then called saprophytes.

The working plant, that is, the plant which takes crude materials from the soil and the air, and makes them into foods, needs light and leaf green for its task.

The leaves of the plant make food for the plant. — Most of the work of food making is done by the leaves since they have the pores through which carbon dioxide enters, since they contain leaf green, and since they receive the best light. If a plant loses a large part of its leaves, the supply of food which it is able to make is so meager that the plant starves to death. The caterpillars, which appear in spring and summer and greedily devour the leaves of trees and bushes, rob our plants of their

power to make food. Some of us wonder why the plants do not constantly grow new leaves to take the place of those eaten by insects. This is because the tree whose leaves have been destroyed by insects has no means of making food, and loses its vigor and its ability to produce new growth.

If we wish our trees and shrubs to remain active and healthy, we must protect them against leaf-destroying insects. Caterpillars should be watched particularly in the early spring and should be removed from plants. A good way to protect the trees is to destroy the insect eggs before they are hatched, or to spray the trees with a substance injurious to the young caterpillars.

Leaves keep the air moist. — Plants require soil food and get it by absorbing water in which minerals are dissolved. The amount of minerals dissolved in ground water is very small, and the roots must absorb enormous quantities of water in order that the plant may get the required amount of mineral matter. The large quantity of water taken in by the roots passes upward through the stems and finally reaches the leaves. Some of this water is used in starch making and the rest is given off through pores in the leaves. This giving off of water through leaf pores, or stomata, is known as transpiration (Fig. 309). Most of us have no correct idea of the quantity of water absorbed by the roots and released by the leaves. It has been calculated that a large, healthy oak tree has about 700,000 leaves and that it throws off to the air

FIG. 309. — Through transpiration water collects in the upper glass.

about 250 tons of water each spring and summer. Because trees give off moisture, they are a great blessing to a community in a hot, dry summer; they take water from the deep underground soil which their long roots penetrate, and give it out to the parched air through their leaves.

Leaf pores or stomata are an extremely important part of a plant. Through them carbon dioxide enters the plant, and surplus oxygen and water escape from the plant. If these pores become clogged, the plant is deprived of the carbon which it requires for food making and is overburdened with oxygen and water which it cannot use. The hedges along dusty roadsides wither partly because their pores are clogged with dirt. The trees along our city streets lose the fresh green beauty in a dry summer, partly because smoke and dust clog their pores.

Plants need air. — Everything which lives, whether it be plant or animal, requires oxygen for life. But the amount of oxygen which a plant takes from the air during respiration is much less than the amount which the plant returns to the air from the carbon dioxide. Thus plants keep the air around them fresh and rich in oxygen.

Public parks and city trees. — Because green plants remove carbon dioxide from the air and supply oxygen to it, they are much needed in large cities where thousands of men are constantly breathing out carbon dioxide and constantly requiring oxygen. Parks and squares with grass, shrubs, and trees should be thickly scattered throughout our large cities, and thriving trees should line our sidewalks. The more abundant our grass plots and trees, the purer is the air breathed by the inhabitants, and the healthier are the lives of the citizens. Parks and public squares are cared for by the community, but the planting and care of sidewalk and garden trees are usually left to the individual householder. The expense of planting a

tree is small, and many a citizen would gladly plant trees if he realized the value of trees to himself, to his family, and to the community. Damp cellars and basements are a bugbear to all householders, and nothing lessens the natural dampness of the soil more than trees. Trees absorb moisture through their roots (Fig. 310) which spread far and wide. The removal of moisture from the soil lessens the dampness of cellars, and improves the general condition of the house. Trees are a great comfort in the hot days of summer, because their leaves

FIG. 310. — Tree roots.

cut off the hot rays of the sun and keep houses and streets cool. In winter when the sun is needed there are no leaves, and the sunshine passes through the bare tree branches and falls upon houses and streets, bringing warmth and cheer. Every citizen should keep in mind the hygienic value of parks and of sidewalk trees, and should insist that they be as much a part of the community as well-paved and well-lighted streets.

Taking care of trees. — Many people admire trees and are glad to have them in gardens or on pavements, but few understand the needs of trees and are willing to give time to them. A tree cannot be planted and left to shift entirely for itself; it must be pruned, must be kept free from caterpillars, must be protected against horses (Fig. 311) by metal guards, and must be watered occasionally during a long dry summer. The owner must not cement close around the tree trunk and shut off air and water from the roots, but must leave a free space around the base of the tree so that rain and water can soak to the roots, and fertilizer can be spread on the soil. A fine, healthy tree cannot be had without care from the owner, but the actual daily care is small, and is far less than the pleasure and benefit yielded by the tree.

FIG. 311. — A tree injured by horses.

The importance to a community of growing plants and trees is now so keenly felt that many cities have permanent Park and Tree Commissions whose duty it is to provide parks for the citizens, to plant suitable trees on the sidewalks, to prune the trees regularly, and to care for them generally (Fig. 312). The expense of this work is paid by a small tax on the citizens, and so far the plan has been successful. The men employed by the commissions are experts who understand what to plant, how to plant, and when to plant. They also understand pruning and spraying for insects, and thus they keep the trees in excellent condition without much direct aid from the household. If, however, such a commission does not exist

*A**B*

FIG. 312. — The life of this elm was preserved (*A*) by removing the decayed part, and (*B*) by filling the cavity with cement.

in your city, do what you can to keep the trees in a healthy condition.

The structure of leaves. — A leaf usually consists of a broad flat part, called the blade, and of a stalk, called the petiole. Sometimes the petiole is missing and the leaf is attached directly to the plant stem. The blade may be of any shape: in grass it is long and very narrow; in nasturtium it is almost circular; in



FIG. 313. — The shape of leaves varies.

poplar leaves it is almost heart-shaped (Fig. 313). Sometimes the blade is indented as in maple leaves; sometimes it is divided up into a number of distinct leaflets as in the rose and horse-chestnuts (Fig. 314). Through the blades of all leaves, no matter what their shape, run numerous conspicuous veins.

When a leaf is held up to the light, a close network of smaller, finer veins is visible (Fig. 315). Veins form the framework of

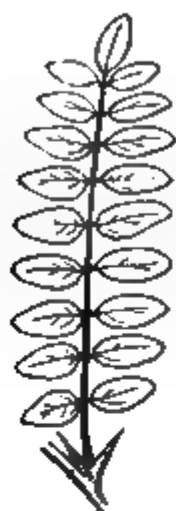


FIG. 314. — Many leaves are compound.

FIG. 315. — Every leaf has a network of veins.

the leaf and give support to it; they also serve as channels for the passage of water and cell sap. Different leaves are characterized by different arrangements of veins: lily leaves are parallel veined; beech and birch leaves are feather veined; maple leaves are palm veined.

Leaves as food for man. —

The leaves of green plants always contain food and man has learned to use many kinds to satisfy his hunger. Such widely known vegetables as cabbage, spinach, water cress, kale, and lettuce are merely clusters of leaves rich in substances agreeable to man's taste and capable of satisfying his hunger (Fig. 316). When we think of the great variety of green leaves and the few that are used for food, we see that we

FIG. 316. — Cabbage and lettuce are clusters of leaves.

have by no means exhausted the sources of plant food. The fact that wild dandelion leaves are becoming popular as a market vegetable is evidence that the future may have many surprises in store for us. Some of the plants which are now despised and are considered weeds will doubtless be cultivated by coming generations and made important garden products.

The danger of unknown plants. — Although all plants contain food substances, it would not be safe for us to gather at random unknown leaves, roots, fruits, and seeds for use as food, because some plants contain substances which when eaten are injurious and even poisonous.

The dainty leaves of the graceful poison hemlock resemble parsley, its thickened root is similar to the parsnip, its tiny seeds are akin in appearance to anise, and it is often mistaken for the harmless plants which it resembles. The root of the old pokeberry is sometimes mistaken for horseradish and parsnip, and when eaten causes serious trouble and sometimes death. The leaves of the marsh marigold and

Jimson weed are sometimes used as "greens" and have frequently been the cause of serious trouble. The dainty Indian tobacco plant is extremely poisonous.

Certain plants, like poison ivy and poison sumac, frequently

FIG. 317. — Poison ivy.

cause itching, swelling, and eruption, if they are merely touched. Jimson weed is particularly dangerous because it grows abundantly in city lots. Children have been made seriously ill by chewing this weed. It is a bushy plant with large leaves and white or purplish flowers. In the late summer it has conspicuous dry fruits full of small seeds. Poison ivy grows along roadsides, climbing over fences, and up tree trunks, to which it attaches itself by tiny air roots. Its leaves (Fig. 317) are deeply notched or three parted, and in spring and summer are a beautiful green color. In late summer they turn to a handsome deep red, and by their brilliant coloring lure many an unsuspecting person into plucking them. But poison ivy, no matter how attractive its appearance, should never be touched.

The uses of stems to the plant. — Leaves cannot make food unless they are exposed to the sunlight and unless they receive an abundant supply of water. Stems, trunks, branches, and twigs are useful to the plant because they lift the leaves upward and outward to the light, and because they carry to the leaves the soil moisture taken in by the root hairs. They are equally useful to the plant in carrying to the roots the food manufactured by the leaves. Two currents of sap constantly flow through stems: one upward from the roots, and the other downward from the leaves.

The structure of stems. — The structure of a stem can be studied by examining a young maple or lilac stem which has been cut in halves lengthwise. The split stem shows three distinct portions: first, an outside covering, the bark; second, a woody portion, the wood; and third, a pithy portion, the pith, at the center (Fig. 318). The bark is extremely important and, when examined closely, is seen to consist of three or more distinct layers, a dry brown layer which is the outermost covering of the stem, a green layer which lies directly beneath the brown, and a tough fibrous layer, the bast, which lies next to

the wood. The tough fibrous section of the bark is made up of strong threads or fibers which run lengthwise down the stem.

When we examine wood from which the bark has just been removed, we find that it is covered with slimy matter. Between the wood and the fibrous bark is the cambium, a layer of delicate cells too small to be seen with the naked eye. The cells of the bark are tough, but those of the cambium are tender and easily torn, and when the bark is pulled from the stem, the cambium breaks and slimy matter oozes out of the cells and spreads over the wood.

FIG. 318. — A cross section of a twig, showing bark (*e*), wood (*w*), and pith (*p*).

The central section or pith is a mass of soft dry matter, formed of cells which have dried up, and are no longer of use to the plant.

The flow of sap through the stems. — You can see how soil food flows upward through the stem by placing young stems of lilac or other plants in red ink and leaving them there for a day. When you remove the stems and split them in halves you see that the ink has risen through the woody section close to the cambium. It is not easy to show how the food sap flows downward, but it has been proved that it passes into the fibrous bark and makes its way through it to the roots. If the fibrous bark of a tree is injured by deep cutting, the downward flow of sap is stopped and the roots suffer for lack of nourishment. The poorly nourished roots are unable to grow or to take in sufficient soil moisture. The upward current of water is small, the leaves droop from lack of water, and the tree dies of slow starvation (Fig. 319).

Girdling a tree is nearly always unwise, because although the

FIG. 319. — The bark of this tree has been injured by wire.

girdle may be loose at first, it becomes tighter as the tree grows, and finally interferes with the food supply of the roots. The person who carves initials on a tree should be careful not to cut deep enough to reach the bast layer. A few deep cuts may not injure a tree, but many deep cuts often ruin fine trees. The bark of the birch tree is easily peeled off and is frequently used in the making of fancy articles, such as jewelry cases, sewing baskets, and post cards. Inhabitants and visitors in regions where birch trees grow should make it their business to protect these trees rather than to destroy them, and should refrain from ruthlessly stripping off the bark.

How small stems grow into large stems. — The growing part of the stem is the cambium layer. In the spring and the summer the cambium cells multiply and form a large layer of wood on their inner surface and a small layer of bark on their outer surface. New wood is formed very much faster than new bark, and old trees contain much more lumber than bark. Each year new wood adds to the thickness of the stem and enlarges it, and the slender trunk of the tiny sapling becomes the large trunk of

girdle may be loose at first, it becomes tighter as the tree grows, and finally interferes with the food supply of the roots. The person who carves initials on a tree should be careful not to cut deep enough to reach the bast layer. A few deep cuts may not injure a tree, but many deep cuts often ruin fine trees. The bark of the birch tree is easily peeled off and is frequently used in the making of fancy articles, such as jewelry cases, sewing baskets, and post

FIG. 320. — A piece of wood in cross section, showing the annual rings.

the older tree. The small twigs of the young tree grow into the hardy branches of the mature tree. The circular rings seen on the cross section of branches and on the stumps of fallen trees show the amount of wood made by the cambium from year to year (Fig. 320).

Succulent stems. — We have only to think of the tender leaves of the sweet pea, of the juicy stem of asparagus, or the stringy

FIG. 321. — Stems used for food.

but soft stem of the peony, to know that stems are not all woody like those of the grapevine, the lilac bush, and the maple tree. Some plants, like the lilac bush and the maple tree,

live on from year to year, become larger and stronger with time, and have woody stems. Other plants, like peonies and violets, die down to the ground after they have borne flowers and fruit, and come up afresh the following spring from protected old roots or germinating seeds. Plants which die down to the ground with the approach of winter are called herbaceous plants or herbs, and have succulent stems in place of the woody stem of long-lived plants. Some of our most popular vegetables are the soft succulent stems of herbaceous plants, for example, asparagus and celery. Stems are not always erect and above ground; sometimes they are under ground and are short and swollen, as in the white potato (Fig. 321). The food made by the leaves of the potato plant is passed down the erect stems above ground to stems under ground, and accumulates there, swelling and bulging them into tubers. You can easily

convince yourself that the white potato is a swollen underground stem by examining it and noting the tiny buds or eyes which are scattered over it. Because buds never grow regularly on roots the white potato cannot be called a root. It is really a swollen underground stem or tuber.

Woody stems as lumber. — Woody stems, branches, and trunks are most valuable for the lumber which they

FIG. 322. — Conifers.

furnish for building purposes. Although iron is used extensively for the framework of modern large buildings, and concrete and stone are used for their exteriors, there are many furnishings such as doors, closets, and moldings, which are rarely made of any substance but wood. In private dwellings wood is almost exclusively used for the framework, floors, and corridors. Hundreds of common articles are made of wood. Over thirty billion feet of lumber have been used yearly for the last one hundred years in the United States alone. More than three fourths of this vast supply has been obtained from conifers, trees which, like the pine, spruce, and cedar (Fig. 322), bear cones and are usually evergreen. The remainder has been obtained from oak, maple, ash, elm, hickory, and other deciduous trees, that is, trees which, unlike the evergreens, lose their leaves at the approach of winter (Fig. 323).

FIG. 323. — Deciduous trees in winter, with an evergreen in their midst.

A widely used wood in this country is white pine. It is light to handle, is soft to saw and nail, and is very abundant, growing in many regions throughout the country. These characteristics have made it an important commercial product and are responsible for its wide use. Oak, another important wood, is strong,

tough, and durable, and is invaluable where great strength and durability are desired, as in the making of farm implements, wagons, and bridges. Walnut, cherry, and mahogany are less common and are used chiefly for ornamental purposes, as in the making of fine furniture and in the finishing of the interior of buildings.

The uses of wood are almost innumerable. The flexible woody shoots and stems of willow trees are woven into strong baskets and hampers (Fig. 324). Small pieces of wood from spruce, poplar, aspen, and other trees are ground into a pulp and made into the paper on which our daily news is printed and our business communications written. Wood

FIG. 324. — Baskets.

can be chemically treated in such a way that it yields wood alcohol, wood or artificial vinegar, and other important commercial products.

Stem fibers. — Strong flexible threads or fibers from plants have for years been woven into such useful articles as twine, rope, fish nets, bags, and into clothing. The most important plant fibers used for clothing are from the cotton and flax plants; the most important plant fibers used for such things as burlap, rope, carpets, and twine are from the hemp and jute plants. Flax is an herbaceous plant which grows about two and a half feet high and has a strong flexible stem. The stalks are cut from the plant and are soaked in water until their weaker portions have rotted and are easily separated from the tough bast threads. The coarser and longer threads are manufactured into twine, and the better fibers are woven into canvas,

duck, and other strong materials. The finer strands are woven into good linens, such as table linen, towels, and handkerchiefs. The finest fibers are made into laces, embroideries, and expensive trimmings.

The bast fibers of jute and hemp are not used extensively in the making of clothing, but they are widely used for potato

FIG. 325. — A flax field.

bags, sailcloths, burlap, curtains, carpets, plush, rope, twine, and other similar articles. The fineness or coarseness of fibers depends greatly upon the manner in which the plants are cultivated. If flax plants (Fig. 325) are crowded together, they

yield fine fibers, but if they are less crowded, they develop into strong and hardy plants and yield coarse fibers. If the plants are pulled when young before their seeds are ripe, the fibers are fine, but if they are allowed to grow until their seeds have ripened, the fibers are coarse.

Stem fibers are not the only ones suitable for commercial purposes. The leaves of the pineapple plant contain fibers of unusual strength and fineness, from which fabrics of the most delicate texture are woven. The fibrous husk which incloses the hard-shelled coconut contains tough enduring strands which make excellent doormats and mattings.

Commercial products. — For years rubber has been used for carriage and wagon tires, overshoes, waterproof garments, life preservers, hose, elastic bands, erasers, and other purposes. But the greatest demand for rubber has arisen since the large and heavy tires of automobile cars and trucks require vast quantities of them. Rubber is obtained from trees which grow in tropical countries (Fig. 326), the finest grades coming from India, Brazil, and the Amazon Valley. Cuts are made in the trunk of the tree and cups are placed to receive the milky juice or latex which flows from the wounds. The juice resembles cream in appearance and consists of minute globules of rubber floating in water. The making of rubber from latex is similar to the making of cheese from cow's milk. The globules of rubber are separated from the watery mass, and are pressed into sheets or into balls.

Turpentine is one of the most important and widely used oils obtained from plants. It is used for dissolving and thinning paints and varnishes, and most of us are familiar with the strong odor of it in freshly painted houses. Turpentine is frequently substituted for quinine in fevers, and is used as a liniment in bandages. Crude turpentine is a thick, sticky liquid which flows from wounds made in the long-needle pine tree.

Camphor comes from the camphor tree. The wood of the tree is cut into small bits and heated with water. As a medicine

FIG. 326. — Gathering sap from rubber trees.

camphor is very valuable, and as a protection against insects it has some value.

Maple sirup is obtained from the hard or rock maple tree in much the same way that turpentine is obtained from the pine. The thin watery sap which runs from the tree is boiled down until it thickens into sirup or hardens into sugar.

CHAPTER XLIV

THE ANIMALS OF THE EARTH

Domestic animals. — Of all the animals of the earth, the most important to man are the farm animals, such as the cow, the sheep, the pig, and the horse. Cows are invaluable because the milk which they yield is the sole food of millions of babies. Milk is secreted by the cow for the nourishment of the young

calf, but man by milking the cow secures the milk for human consumption.

A good cow yields 4000 pounds of rich milk a year, and many cows, such as the best Guernseys, yield much more.

The quantity of milk yielded by a cow is

FIG. 327. — The Jersey cow gives rich milk

not always the most important factor, because milk must be rich in fat as well as abundant in quantity. The quantity and richness of milk depend to a great extent upon the care the animal receives; good feeding, cleanliness of the stable, airy, light stalls, and careful milking enrich the milk and make it more abundant (Fig. 327).

The young lamb, like the young calf, receives food from its mother; this is also true of the young goat. But man has

never used the milk of the sheep for food. Sheep are raised only for meat and wool. In the United States, goat's milk is not much used for food, but in Europe it is used extensively, especially in mountainous regions. The goat requires less attention than the cow, and scrambles over steep slopes and lives well on land too poor for the cow.

Cows are valuable for their meat as well as for their milk, but good milch cows are not always good meat cows. Cattle-



FIG. 328. — Loading beef for export.

men raise two breeds of cows, a breed which gives unusually good milk, and a breed which furnishes unusually good meat but poorer and less abundant milk. Some of the choicest cuts of meat, such as tenderloin, sirloin, porterhouse, come from the cow, and also some of the cheaper but equally nutritious cuts, such as chuck, rump, and neck (Fig. 328).

Practically every part of the cow is valuable; those parts which cannot be used for meat, such as hide, hoofs, horns, hairs,

and bones are made into leather, glue, tallow, buttons, combs, brushes, and fertilizer.

Sheep yield mutton and wool, and, if properly cared for, make good money returns. They thrive on scanty vegetation and in pastures too poor for cows, but in winter their quarters must be as carefully kept as those of the cow. Our finest clothing is made of pure wool and among our choice meats are roast lamb and lamb chops (Fig 329).

FIG. 329. — Merino sheep.

Pigs are raised at practically every country house. This is because they are easily cared for and because they yield, when slaughtered, meat which is easily preserved as ham, bacon, and salt pork. Pigs cost their owners little because they are fed garbage (clean, wholesome garbage), corn fodder, and refuse, such as potato peelings and apple parings. Because of the cheapness and ease with which they are kept, they yield large profits (Fig. 330).

FIG. 330. — Pigs are profitable animals.

In the United States horses are considered valuable because they are good beasts of burden. The draft or working horse has large hoofs, strong feet, short legs, and a heavy body. The

carriage horse has smaller hoofs, is long legged, and has a less stocky body. The average horse is the intermediate between these and is able to do moderately heavy work and at the same time serve as a carriage horse.

The cow, the sheep, the pig, and the horse belong to a group of animals called mammals. They bear their young alive and nurse them. Cats, dogs, and rabbits also belong in this group. Mammals have either a short, thick, hairy covering like the horse and the cow, a fine inconspicuous, hairy covering like man, or a short thick fur like the sheep or the rabbit (Fig. 331).

FIG. 331. — A rabbit.

Among mammals are found some harmful animals. The house rat, for example, is known throughout the world as a pest to farm, factory, ship, and house. Rats not only destroy good food, but they also injure buildings and furniture by their gnawing, and, what is worse, they spread disease. The frightful bubonic plague is spread by rats and a bonus is placed on dead or living rats in infected cities. Field mice are a pest to the farmer, undermining his fields and destroying his crops (Fig. 332).

Poultry. — Chickens are greatly in demand for meat, but their chief value is in the eggs which they lay. About twelve billion eggs are used in the United States yearly. Even then the demand is far greater than the supply. Eggs are nutritious, easily digested, and usable in innumerable ways, and

their place in the kitchen cannot be taken by any other product (Fig. 333).

Chickens, unlike mammals, do not bear young alive, but lay eggs from which chicks may hatch. In order that the chicks may hatch, the eggs must be kept warm by the hen for 21 days. Man has learned that the sitting hen does nothing more than keep the eggs warm enough to develop the embryo chick. He therefore gathers freshly laid eggs and places them in incubators or heated boxes, where they hatch into chicks. In this way the young chicks are under his eye and can be fed and cared

FIG. 332 — A crop destroyed by mice.

for. What are some of the dangers to which young chicks are exposed when left to shift for themselves? Chicken meat is delicate and is easily digested and is a valuable change in diet for those who can afford it.

Turkeys, ducks, and geese (Fig. 334) are raised on some farms, the first two for food, the latter for both food and feathers. The turkey is an American bird and is little known outside of this country. The barnyard turkey is the



FIG. 333. — A good kind of poultry.

descendant of the wild turkey which was abundant in America at the time of its early settlement. Domesticated turkeys retain much of their wild nature, and wander away from the farmyard and are easily lost to their owner. They are difficult to raise and are therefore scarce and expensive.

Chickens, turkeys, geese, and ducks belong to a group of feathered animals called birds. Birds do not bear their young alive, but lay eggs from which the young hatch. They are covered with feathers, which

FIG. 334. — Geese.

keep them warm and aid them in flight. Domesticated fowls have largely lost the use of their wings and can fly but short distances.

Fish. — Next to mammals and birds the most important animals to man are fish. Cod, herring, shad, mackerel, perch

FIG. 335. — The common perch.

(Fig. 335), bass, and salmon are used extensively for food, and thousands of men are employed in the fishing industry. The salmon of the Pacific coast is alone worth \$13,000,000 yearly, and the cod of the Atlantic coast over \$2,000,000. Some fish,

like pike, pickerel, and whitefish, live in fresh water and can be caught in lakes and streams throughout the country. Others, like haddock, live in salt water and can be caught only in the open sea. Still other fish, such as salmon, shad, and smelt, spend part of their time in salt water and part in fresh water, and can be caught in either place. The habits of some fish make it easy to catch them in large numbers; they usually swim in

FIG. 336. — A large fish net.

groups, called schools, and a single haul of a net or a weir may bring in hundreds and even thousands of fine specimens (Fig. 336).

In the United States, the most important fish are cod, shad, herring, and salmon. All of these spend the greater part of their life in the ocean, but leave the rough waters at the egg laying season and swim up the rivers in search of a quiet place in which to spawn or lay eggs. As soon as this journey upstream begins, fishermen set their nets and weirs and haul in vast

numbers of them. The fish that escape make their way farther upstream, where they finally deposit eggs. The young which hatch from the eggs remain in the fresh water until they are large and strong enough to make the journey back to the sea, where they stay until they become adults and are able to spawn.

Reproduction among fish is very different from that of either mammals or birds. At the spawning season, which is usually spring or early summer, the female discharges eggs from her body, and the male deposits a milky substance called milt over them. In order that eggs may hatch into young fish, it is necessary that they come in contact with sperm cells in the milt. If eggs are carried away by waves and wind before milt comes in contact with them and fertilizes them, they fail to hatch and

FIG. 337. — Stripping and fertilizing eggs at a hatchery.

quickly decay. The number of eggs laid by fish is enormous, a single trout laying thousands, a single shad hundreds of thousands, and a single cod several millions of eggs. The roe of shad, which is such a popular dish in the spring, is the egg mass of the female shad. If the female shad is not caught, but is left in the water, the skin of the roe bursts and sets free the eggs, which escape into the water and, if fertilized, develop into young shad. Of all the vast number of eggs produced by the female, few develop into mature fish, because many of the eggs perish

before the milt reaches them and many of the young fish which develop from the fertilized eggs are greedily eaten by birds and other fish.

In the early days of America the rivers teemed with fish, but the number rapidly diminished because more and more were caught for food, and fewer and fewer were left to spawn. Within recent years, the government has undertaken to raise fish artificially and has erected fish hatcheries in many places. Male and female fish are caught by government fishermen.

The eggs are gently pressed from the body of the female into a moist bucket, and the milt is pressed from the body of the male and spread over them (Fig. 337). The fertilized eggs are put in water and left to hatch and develop into young fish. The young

FIG. 338. — Spawning pond, or trough.

fish are cared for until they can care for themselves; then they are placed in near-by streams and lakes or are shipped in large cans to remote streams and lakes. If the hatcheries are large, the fishermen bring in male and female fish and place them in large troughs of running water (Fig. 338), where they remain until they spawn. The adult fish are then removed from the troughs and put back into the streams, and the spawn is left in the troughs to hatch and develop into fry.

In spite of the fact that the government, through the Bureau of Fisheries, stocks streams yearly with many fry, the supply of

fish remains small. In order to increase the supply, laws have been enacted for the protection of fish; bass and trout, for example, cannot be caught during the breeding season, and salmon cannot be caught except on definite days of the week; and certain other fish cannot be caught unless they are large enough to have had a chance to spawn.

Vertebrates. — Farm animals and fish have a jointed and flexible backbone, or vertebral column, and hence they are called vertebrates. The vertebral column serves as a place of attachment for the larger bones of the body, and also serves as a support or skeleton for the soft parts of the body, such as heart, kidneys, and stomach. To the backboned or vertebrated animals belong frogs (Fig. 339), toads, and reptiles, but these animals are not directly important to man for food or clothing and are not studied here.

FIG. 339. — A frog

With the exception of fish, most vertebrates live on land, and get oxygen directly from the air by means of lungs. Fish live in the water, and secure the oxygen they need from the air which is in solution in the water. Fish take oxygen from the water by means of gills which are feathery, red structures on each side of the head. Most of the water which enters the mouth is not swallowed, but is passed over the gills, and is then expelled through openings in the side of the head. As the water flows over the gills, the oxygen dissolved in it passes through the thin gill walls, and becomes part of the blood. In this way fish secure a constant supply of oxygen.

In most vertebrates, except fish, the waste product, carbon dioxide, is discharged through the lungs; in fish it is discharged through the gills. As water flows over the gills it absorbs carbon dioxide from the blood and carries it away with it through the gill openings on the side of the head.

The absorption of oxygen through the gills into the blood, and the discharge of carbon dioxide through the gills into the water keeps the blood of the fish pure, and the gills serve the fish as effectively as lungs serve the other vertebrates.

Oysters. — Next to farm animals and their products, and fish, oysters are the most important animal food. Oysters live in the

shallow water near ocean coasts, attached to stones, rocks, and shells. They are found in the United States along both the Atlantic and the Pacific coasts. In Long Island Sound, Chesapeake Bay, and the

FIG. 340. — The inside of an oyster. (From Brooks's *Oyster*.)

Gulf of Mexico immense quantities of them are obtained by dredging. The edible part of the oyster lies between two rough thick shells of limestone which are hinged together at one end (Fig. 340). When the oyster is undisturbed, the upper shell or lid is raised and water enters; when the oyster is disturbed or threatened by enemies, the lid is drawn down by a strong muscle and fits tightly against the lower shell. The tough portion which we notice when eating an oyster is the muscle which opens and closes the shell.

• Reproduction in oysters is similar to reproduction in fish: females discharge eggs and males discharge milt. The

young which hatch from fertilized eggs are totally unlike the parent in appearance and habit; they have no shells and swim about on the water. In time they secrete a thin shell and sink. If they fall upon a muddy bottom, they are smothered, but if they fall upon a gravelly, stony, or rocky bottom, they live and grow and within a few years become full grown. As the soft part of the young oyster grows the shell also grows and is always large enough to cover the defenseless creature within it. In spite of the fact that the female oyster lays millions of eggs yearly, the supply of oysters is too small to satisfy the demand for them. This is because many are

FIG. 341 — Oyster trays. (From Brooks's *Oyster*.)

smothered in muddy bottoms, many are killed by overcrowding, and many more are attacked by enemies which destroy them in spite of their hard shell. In order to increase the supply, oysters are raised artificially on some parts of the coast. Large beds of stones, stakes, or trays (Fig. 341) are built at the bottom of the water to prevent smothering, and care is taken that the growing oysters are not overcrowded and are not disturbed by enemies.

Clams are soft-bodied animals protected by shells, and are similar to oysters. They are eaten extensively in the United States. Clams do not remain fixed in one place as do oysters,

but move about by means of a strong muscle which they extend beyond the shell.

Oysters, clams, and all soft-bodied animals which are protected by shells are called mollusks; in some mollusks, such as snails (Fig. 342), there is only one shell; in other mollusks, such as oysters and clams, there are two shells.

Flies. — Four fifths of all animals are insects, a group which, except for the honeybee and the silkworm moth, do not contribute food and clothing to man. But this enormous group of animals plays an important part in our lives, because some of them, like the fly and the mosquito, spread disease; others, like the corn worm and the potato beetle, destroy crops; and still others, like the roach, infest our dwellings.

The two insects which are most injurious to health are the fly and the mosquito. The fly seems harmless because of its size. If it were so large that we could see the hairs which cover its body and its six legs, we would not tolerate it for an instant, because these hairs are always clogged with filth and germs. On the end of each of the six feet is a tiny pad moistened by a sticky secretion which enables the fly to walk on smooth surfaces such as window-panes, ceilings, and edges of dishes. As the fly crawls from place to place the pads on the feet and the hairs all over the body pick up dust and filth, and when the fly alights on our meat, preserves, and bread, it contaminates the food with filth. Flies are indiscriminating creatures, and visit sputum in the street, sewage plants, and rotting dump heaps as eagerly as they visit the food in our kitchens. The filth gathered from street, dump heap, and sewage reeks with disease germs, and food over which flies have walked is probably contaminated with the germs of tuberculosis, typhoid fever, and other diseases, and is capable of causing illness.

Warfare by "swatting" is one method of decreasing the number of flies; but a single escaped fly breeds so rapidly that victory over the pests can be had only by removing all breeding places for the young. The adult fly lays her eggs, about one hundred at a time, preferably in horse manure, but she will also lay them in any decaying matter and even in fresh meat. In order to lessen the number of breeding places, every city should require livery men to keep manure carefully screened from flies, and grocery men and housewives to keep garbage and refuse in covered cans. Every

FIG. 343. — Eggs, maggots, and adults of the fly.

city should do away with dump heaps and should dispose of garbage in scientific ways. Every individual should see to it that his home, his shop, and his office are free of breeding places. Screened or covered food, yards, and pavements free from banana skins, apple peelings, bits of meat, and other refuse, and clean privies screened against flies offer no opportunities for egg laying and are powerful aids in the extermination of the fly.

The eggs of flies hatch in one day into larvæ or tiny white, footless maggots (Fig. 343) which worm their way about and eat greedily. As they feed and grow, their skin, which is inelastic, becomes too tight for them and finally splits; the growing maggot pulls itself out of its split or molted skin and appears with a soft new skin. For a time the new skin remains soft and elastic and the maggot grows rapidly. But in time the skin hardens and becomes inelastic; it again splits

and is shed or molted by the maggot. Both of these molts occur in less than a week from the time of hatching. At the end of a week, the inelastic skin turns brown, the creature within it shrinks away from it, and as far as we can see remains inactive for a week. In this stage it is called a pupa. But great changes take place in the maggot during this period, because at the end of the week of quiet an adult fly emerges from the brown skin.

It requires only two weeks for the 100 eggs laid by a single fly to develop into 100 adult flies. Since most of these flies lay 100 eggs apiece, the number of flies in the community rapidly increases and becomes a serious menace to health.

Mosquitoes. — The mosquito is an annoying creature, and by its buzzing and biting interferes with our pleasures out of doors and our comforts at home. But its buzzing and stinging are not the worst charges against a mosquito. The strongest reason for dislike of it and warfare against it is that it is a carrier of malaria and yellow fever, and is thus a breeder of disease. Malaria is caused by a germ which lives in the blood of a malarial patient; when a mosquito bites a person sick with malaria, some of the germs get into the mosquito's body and multiply there. When the mosquito bites another person, some of the malaria germs get into the wound made by its sharp mouth. These germs grow and multiply and spread through the blood of the bitten person and cause malaria.

Mosquitos, like flies, breed rapidly and the best way to decrease their number is to destroy their breeding places. About 200 eggs grouped together in an irregular mass are laid on the surface of stagnant water by each female. The water in a gutter, in an automobile rut, in an open rain barrel, in the urns of cemeteries, in flower pots, or in discarded tin cans, serves as a breeding place for hundreds of mosquitoes. Larger breeding places are furnished by ponds, pools, and marshes.

Within a day, the eggs hatch into larvæ or small squirming

creatures called wigglers. The most noticeable things about a wiggler are that a tube projects from its body near the posterior end and that the wiggler frequently thrusts this tube out of the water and hangs suspended head down from the surface of the water. The tube is a breathing organ and is thrust out of the water for air. As soon as a wiggler has a supply of air, it is free to move through the water; when the supply is exhausted, the wiggler returns to the surface for more.

The young wigglers feed greedily on living things which they find in the water and grow rapidly, molting their skins several times. After a week they change into a totally different form, the pupa, very much as the fly does. The pupa of a mosquito is characterized by two projections in the upper and forward end of the body. These are breathing tubes and project out of the water most of the time. In three days the skin of the pupa bursts, and an adult mosquito works its way out. It floats on the skin until its wings are dried by the air; then it flies away. If the adult mosquito is a male, it leads a harmless life, feeding on the juices of plants or doing without food. If it is a female, it pierces the skin of man and other animals and lives on their blood, causing great annoyance and spreading disease.

Since mosquitoes lay their eggs only in quiet waters, such as ponds, pools, and marshy lands, if ponds, pools, and marshes are drained or filled up, the mosquitoes lose their breeding places and die without reproducing. If it is not possible to drain the land or to fill it up, oil can be used to destroy the breeding places. A thin layer of oil on water smothers the wigglers which are already there because they cannot pierce through the oil and secure air; it kills all eggs which are on the water, and it also kills all mosquitoes which touch it in their attempt to lay eggs beneath it. The thinnest film of oil is sufficient to destroy mosquitoes, and very little is needed

to cover even large surfaces. Many communities regularly pour oil upon stagnant waters in the spring just before mosquitoes begin to lay eggs, and thus protect themselves against large hordes of the pests. Many fish greedily devour wigglers, and a good way to lessen the number of mosquitoes is to keep all ponds and lakes and bodies of quiet water well stocked with fish.

Some insects destroy crops. — Farmers and nurserymen are troubled by innumerable insects that destroy their crops and injure their trees. Potato beetles, cabbage caterpillars, tree borers, mealy bugs, cotton weevils, squash bugs, brown-tail moths, gypsy and tussock moths do immense damage (Fig. 344).

The squash bug is so abundant that it can be found almost everywhere in fields. It gets its name from the fact that it lives preferably upon squash and pumpkin vines and similar plants. The adult squash bug has a strong, sharp beak and with it easily pierces leaves and shoots and obtains food by sucking up the plant juices. In July the female squash bug deposits eggs on the under side of leaves and from these eggs young squash bugs or nymphs hatch out which are like the parent except that they are very small and have no wings. The young squash bug has strong, sharp jaws and greedily bites and chews the leaves around it and grows rapidly, soon becoming too large for its skin.

FIG. 344. — A piece of wood destroyed by borers.

Within a short time it molts its skin and appears with small wings; with each successive molt the nymph increases in size and the wings become larger and stronger.

Finally the skin splits for the last time, and an adult with full-fledged wings appears.

The potato beetle is a very destructive insect and causes enormous loss to farmers. The adult has strong jaws with which it bites the leaves of potato vines and destroys the plant. The female lays over 500 eggs a summer, in clusters on the under side of the leaf of the potato plant. The young larvæ which hatch from the eggs feast on the leaves for two weeks and sometimes strip the vines of all leaves. At the end of the two weeks of this greedy feeding the larvæ bury themselves in the earth as pupæ and remain there for ten days. Then they leave their pupa skins and appear above ground as adult beetles (Fig. 345).

The life history of the squash bug is simpler than that of the fly, mosquito, and potato beetle. The eggs of the squash bug hatch into nymphs or young squash bugs which resemble the parent except for size and wings; but the eggs of the fly and beetle hatch into larvæ which are totally unlike the parent, and which must pass through a pupa stage before they become adults like the parent. Some larvæ, like the fly and mosquito larvæ, have no protection during the pupa period except their last larva skin; others, like silk moth larvæ, spin cocoons or build cases in which to pass the pupa stage; the caddis fly larva, for example, builds a case of mud and stones in which it rests during its change or metamorphosis to an adult fly.



FIG. 345. — This bug destroys potatoes.

Characteristics of insects. — At first sight there seems little similarity between a potato beetle, a butterfly, a roach, a clothes moth, and a grasshopper. But all of these animals are classed as insects because in their adult form they have certain definite characteristics in common. All have three distinct regions to

the body, namely, head, thorax, and abdomen; on the head of each are eyes, mouth, and jointed feelers; on the thorax are three pairs of jointed legs; and the abdomen of each is made up of distinct rings or segments. Can you find all of these parts on a grasshopper? on a butterfly?

Insects and mollusks are invertebrates, that is, animals without a vertebral column or backbone.

Helpful insects. — Many insects are helpful to man: the silk moth larva furnishes silk; the bee, honey; a scale insect in Mexico, cochineal, a red coloring matter; a Chinese insect secretes wax, and an India insect is responsible for lac, a substance from which varnish is made. But the most valuable insects are those which, like bees and wasps, visit flowers for nectar, and in so doing transfer pollen from flower to flower and assist in the formation of fruit and seed.

How birds help the farmer. — Most song birds live upon insects that destroy crops. Flycatchers take their living from the insects that swarm in the air. Vireos live upon measure worms and similar morsels. A flock of birds may detect a small body of locusts early in the season, and devour them before they find opportunity to lay their eggs. Thus a great disaster to the corn crop may be averted, for when the breeding of the locusts goes on unchecked, they sometimes descend in vast clouds and feed upon growing corn, grass, wheat, and trees, and in a few hours destroy every green thing in sight over an area

FIG. 346. — Robin's nest.

of many square miles. Such a loss of food materials means higher prices to the consumer.

People who do not understand the value of birds in thus protecting crops, often kill them for food or for their plumage. Are such people good citizens?

A short time ago, 30,000 robins (Fig. 346) were brought into the market of one of our large cities in a single day by hunters who had shot the birds for food.

If there is an Audubon society in your state, join it and do your part as a good citizen in checking the slaughter of birds. One writer goes so far as to say "that the greatest danger with which agriculture is, or ever has been, threatened lies in the wholesale destruction of birds now being carried on."

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